A MANUAL

OF

CHAIN SURVEY

FOR

KARNAMS AND REVENUE SUBORDINATES.

MADRAS:
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A MANUAL OF CHAIN SURVEY FOR KARNAMS AND REVENUE SUBORDINATES.

Chapter I.—Elementary Arithmetic.

To follow intelligently the operations described in this manual and to obtain a practical knowledge of land surveying, the reader should be thoroughly familiar with the first four rules of Arithmetic—*addition*, *subtraction*, *multiplication* and *division*—and the extraction of *square-root*. These processes are briefly noted below to refresh the reader's memory :—

Addition.

2. *Addition* is the process of adding two or more numbers of the same kind or denomination to one another. Its sign is *plus* +.

Examples.

9 + 7 = 16	12,34,567
24 + 36 = 60	7,65,432
113 + 224 = 337	87,654
	9,876
	765
	78
	9
	20,98,381

Subtraction.

3. *Subtraction* is the process of taking a lesser number from a greater number of the same kind or denomination. Its sign is *minus* –.

Examples.

6 – 4 = 2	89,65,432
69 – 34 = 35	68,96,549
178 – 129 = 49	20,68,883

Multiplication.

4. *Multiplication* is the process of adding to itself any given number as many times as there are units in any other given number. The result is called the *product*. Its sign is ×.

Examples.

$9 \times 8 = 72$
$12 \times 13 = 156$
$123 \times 136 = 16,728$

```
    895876
      1345
   -------
   4479380
  3583504
 2687628
895876
----------
1204953220
----------
```

Division.

5. *Division* is the process of finding how many times one number is contained in another. Its sign is ÷.

Examples.

$8 \div 2 = 4$
$96 \div 16 = 6$
$720 \div 144 = 5$

```
Divisor   Dividend    Quotient
  956 ) 6,98,70,056 ( 73,085
        6692
        ----
         2950
         2868
         ----
          8205
          7648
          ----
           5576
           4780
           ----
Remainder   796
           ----
```

Square-root.

6. A number squared is the product obtained by multiplying that number by itself; thus, 4 squared is 16 and is denoted 4^2. The *square-root* of a number is that number which, when multiplied by itself will produce the given number; thus 5 is the square-root of 25. The sign of the square-root is $\sqrt{}$; *e.g.* $\sqrt{25} = 5$.

7. To extract the square-root of 6,374,543. Place a dot over the last figure and also over every alternate figure to its left. The object of doing this is to indicate the pairs of figures that should be taken together and added to the dividend in the process explained below. A pair consists of the figure over which the dot is placed and that to the left of it. The number of the dots will also show the number of digits in the square-root to be obtained.

In the example given, there is no figure preceding 6 over which the dot is placed. We therefore take 6 alone and find that the greatest square root contained in it is *2*. This will be the first figure of the root. Subtract the square of *2*, *i.e.*, *4* from *6*. The remainder is *2*. To this annex the two figures up to the next dot, *i.e.*, *37*. Then double *2*, the first figure of the root, and place the product, *i.e.*, *4* to the left of the new dividend *237*. With 4 as a divisor, divide *23* (the last figure *7* being omitted for a moment). We get *5*, which will be the next figure in the root and must also be subjoined to the divisor. Multiply the divisor *45* by *5*, the last figure in the root; subtract the product from *237*. We get a remainder of *12*. Then bring down the next two figures *45* and annex them to *12*. Double *25*, the first two figures of the root and place the product, *i.e.*, *50* to the left of the new dividend *1245*. With *50* as a divisor, divide *124* (the last figure *5* being omitted). We get *2*. This is the next figure in the root and must also be added to the divisor *50*. Multiply the divisor *502* by *2*, the last figure in the root, and subtract the product from *1245*. The remainder is *241*. Then bring down the figures of the next dot, *i.e.*, *43* and repeat the process. We get *4* as the last figure in the root and also a remainder of 3967, the divisor being 5044. When the remainder is either half or more than half of the divisor, we raise the last figure in the root by one. If the remainder is less than half of the divisor, we ignore it. Thus the square-root of 63,74,543 is 2,525.

```
  . . . . Root
  6374543(2524
  4
  ----
45)237
   225
  ----
502)1245
    1004
  ------
5044)24143
     20176
     -----
      3967
      ----
```

Exercises.

Extract the square-root of—

					Answers.
(1)	1,42,884	..	..	..	378
(2)	2,94,849	..	..	..	543
(3)	10,81,600	..	..	..	1,040
(4)	9,78,121	..	..	..	989
(5)	12,56,641	..	..	..	1,121
(6)	13,34,025	..	..	..	1,155
(7)	22,92,196	..	..	..	1,514
(8)	28,22,400	..	..	..	1,680
(9)	58,51,561	..	..	..	2,419
(10)	60,76,225	..	..	..	2,465
(11)	62,40,004	..	..	..	2,498
(12)	61,70,256	..	..	..	2,484
(13)	45,92,449	..	..	..	2,143
(14)	43,97,409	..	..	.	2,097
(15)	39,92,004	..	..	.	1,998

Chapter II.—Definitions of Simple Geometrical Terms.

A line.

A line is the distance between *two* points. It has neither breadth nor thickness. Lines may be *curved* or *straight*. See Fig. 1.

Fig. 1.

A point.

A point is that which has position only.

A straight line.

2. *A straight line* is the shortest distance between two points such as the corners of a field (Fig. 1).

An angle.

3. *An angle* is a bend or corner formed by two straight lines meeting each other (Fig. 2). If the ends of two straight lines meet at a point, they form two angles—one is called the *interior* and the other the *exterior* angle.

Fig. 2.

If three straight lines meet at a point, they form three angles—and so on for any number of straight lines—*vide* Fig. 3.

Fig. 3.

A right angle.

4. When one straight line falls upon another straight line so as to make the two adjacent angles equal to each other, each of these angles is called a right angle and the straight line falling on the other is called a *perpendicular* or in surveying an *offset* to it—*vide* Fig. 4. If these two straight lines cross each other, they form four right angles. (Fig. 5.)

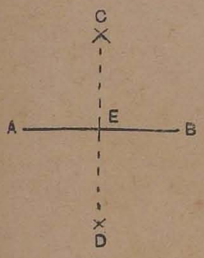


Fig. 5.

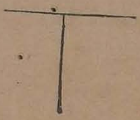


Fig. 4.

An obtuse angle.

5. An angle greater than a right angle is called an *obtuse angle.* (Fig. 6.)

An acute angle.

6. An angle less than a right angle is called an *acute angle.* (Fig. 6.)

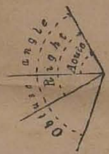


Fig. 6.

A triangle.

7. Two straight lines cannot enclose a space. A field must therefore have at least three sides. A figure of three sides and three angles is called a triangle. (Fig. 7.)

Any two sides of a triangle are together greater than the third side, otherwise no triangle can be formed on the ground nor plotted on the paper—*vide* Figs. 8 and 9. In Fig. 7, AB is 267, BC, 525 and CA, 432.

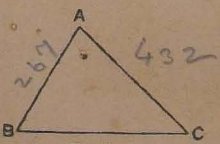


Fig. 7.

525

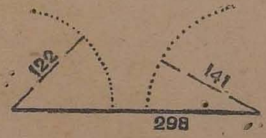


Fig. 8.

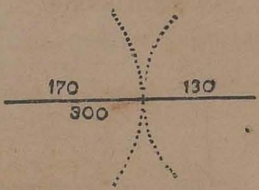


Fig. 9.

A right-angled triangle.

8. When one angle in a triangle is a right angle, the triangle is called a *right-angled triangle.* One of the two sides containing the right angle is called the base and the other the *perpendicular.* The side opposite to the right angle is called the *hypotenuse.* In Fig. 10 ABC is a right-angled triangle with the right angle at B. AB is the base, BC the perpendicular and AC the hypotenuse of the triangle.

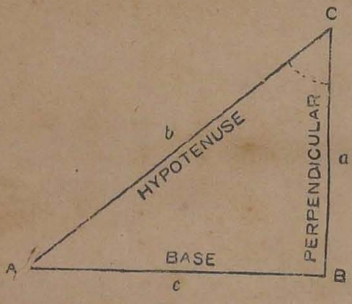


Fig. 10.

Similar triangles.

9. Triangles are said to be similar when the angles in the one are equal to the angles in the other each to each. The sides opposite to or containing equal angles are proportional. In Fig. 11 the angles at A, B and C are equal to the angles at D, E and F, respectively. AB is to BC as DE is to EF; BC is to CA as EF is to FD; CA is to AB as FD is to DE.

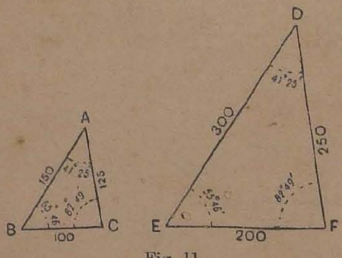


Fig. 11.

A quadrilateral.

10. *A quadrilateral* is a four sided figure. The straight line which joins opposite angles of a quadrilateral, thus dividing it into two triangles, is called a *diagonal* (*vide* Fig. 12).

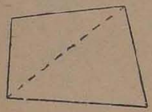


Fig. 12.

A square.

11. If all the angles of a four-sided figure are right angles and all its sides equal, it is called a *square*. (Fig. 13.)

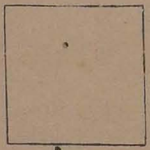


Fig. 13.

A rectangle.

12. If all the angles of a four-sided figure are right angles but its opposite sides only are equal, the figure is called a *rectangle*. (Fig. 14.)

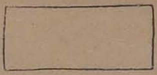


Fig. 14.

A trapezoid.

13. *A trapezoid*, as far as this manual is concerned, is intended to apply to a figure with two of its sides parallel and two of its angles right angles.

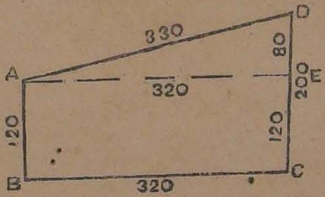


Fig. 15.

A polygon.

14. *A polygon* is a rectilineal figure of more than four sides. It may be divided into triangles by drawing straight lines from one corner to another opposite to it. (See Fig. 16.)

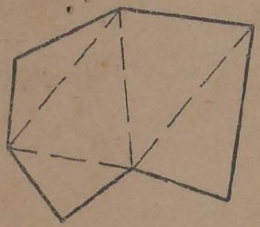


Fig. 16.

Parallel straight lines.

15. *Parallel straight lines* are those drawn in the same direction, the perpendicular distance between which is always the same. The lines if produced to any length both ways do not meet. (See Fig. 17.)

Fig. 17.

3rd Evening.

Chapter III.—Properties of right-angled Triangles and Trapezoids.

Calculation of the third side in a right-angled triangle where two sides are known.

The chief characteristics of a right-angled triangle are—

(1) The hypotenuse is longer than either of the two sides containing the right angle.

(2) The square on the hypotenuse is equal to the sum of the squares on the sides containing the right angle.

(3) The square on one of the sides containing the right angle is equal to the difference of the squares on the hypotenuse and the other side containing the right angle.

Examples.

In figure No. 17-A, ABC is a right-angled triangle with the right angle at B.

AB is 200 and BC, 210.

$$AC^2 = 200^2 + 210^2.$$
$$\therefore AC = \sqrt{200^2+210^2} = 290$$
$$BC^2 = 290^2 - 200^2.$$
$$\therefore BC = \sqrt{290^2-200^2} = 210$$
$$AB^2 = 290^2 - 210^2.$$
$$\therefore AB = \sqrt{290^2-210^2} = 200.$$

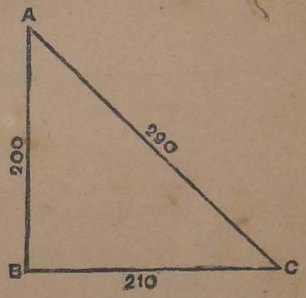


Fig. 17-A.

Where perpendiculars fall on a straight line from points on either side, how the distance between the two points is calculated.

2. If on a given base line perpendiculars are drawn from points situated on either side of it, the distance between the points is found by adding the square of the sum of the two perpendiculars to the square of the distance between the two perpendiculars and extracting the square root of the resultant figure.

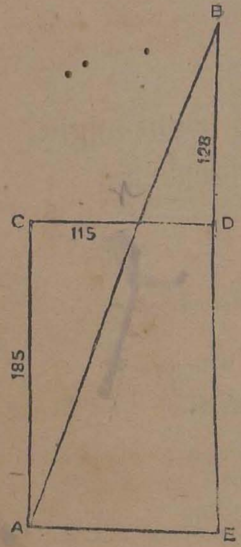


Fig. 18.

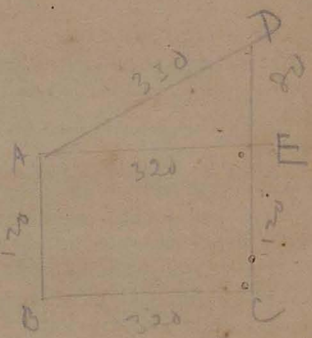
In figure No. 18, AC and BD are perpendiculars on the base CD.

CAED being a rectangle, CA = DE : CD = AE.

BE being made up of BD and DE.

$AB^2 = BE^2$, *i.e.* $(BD + DE)^2 + AE^2$, *i.e.*, CD^2.

$AB = \sqrt{(128 + 185)^2 + 115^2} = 333.$



Relation between the sides of a right-angled triangle when a perpendicular is drawn from the right angle to the hypotenuse.

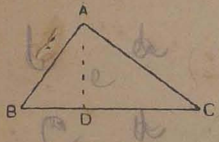


Fig. 19.

3. If in a right-angled triangle, a perpendicular be drawn from the right angle to the hypotenuse, the other sides of the triangle, the segments of the hypotenuse and the perpendicular so drawn bear the following relation to one another :—

In figure No. 19, AD is the perpendicular on the hypotenuse BC.

(1) $AB \times AC = AD \times BC$.
(2) $AB^2 = BD \times BC$.
(3) $AC^2 = DC \times BC$.
(4) $AD^2 = BD \times DC$.

Calculation of the fourth side of a trapezoid when three sides are known.

4. If any three sides of a trapezoid are known, the fourth can be ascertained. Suppose in the trapezoid ABCD, figure No. 15, AB, BC, CD are known. AD can be found thus :—

The trapezoid ABCD is made up of the rectangle ABCE and the right-angled triangle AED. In the rectangle ABCE, AE = BC and EC = AB ; DC being made up of DE and EC and EC being equal to AB, DE can be found by subtracting AB from DC. AE and DE which constitute respectively the base and the perpendicular of the right-

angled triangle AED being thus known, the hypotenuse AD can be ascertained by the method explained *supra*.

$\therefore$ AD $= \sqrt{320^2 + 80^2} = 330$.

Suppose AD, DC and CB are known, AB can be found thus :—

In the right-angled triangle AED, the hypotenuse is 330 and AE = 320 being equal to BC.

DE is therefore $= \sqrt{330^2 - 320^2} = 80$.

But the whole of CD = 200, CE is therefore = 120; AB being equal to CE, AB is equal to 120.

Similarly if AB, BC and AD are known, CD can be found thus :—

AE being equal to BC, AE = 320.

$\therefore$ ED $= \sqrt{330^2 - 320^2} = 80$.

CD = CE + ED ; CE being equal to AB, CD = 120 + 80 = 200.

Exercises for calculation of sides of right-angled triangles and trapezoids.

1. The sides containing a right angle are 404 and 383. What is the side subtending that angle? Ans. 557.

2. The hypotenuse of a right-angled triangle is 378 and the base 159. Find the perpendicular. Ans. 343.

3. The perpendicular and the hypotenuse of a right-angled triangle are 267 and 503, respectively. Find the base. Ans. 426.

4. The length of each of the sides of a triangle is 484. Find the length of the perpendicular drawn from the vertex to the base of the triangle. Ans. 419.

5. The length of a perpendicular drawn from the vertex of a triangle having equal sides is 249. Find the sides of the triangle. Ans. 288.

6. One of the sides of a square is 252. Find the diagonal. Ans. 356.

7. The diagonal of a square is 603. Find the sides. Ans. 426.

8. The perpendicular and the base of a right-angled triangle are 454 and 368, respectively. Find the length of the line joining their middle points. Ans. 292.

9. The perpendicular and the base of a right-angled triangle are 276 and 372, respectively. Find the length of the line joining the vertex with the middle point of the base. Ans. 333.

10. ABD is a right-angled triangle, in which the angle BAD is a right angle. The triangle is split up into two right-angled triangles by letting a perpendicular AC fall on BD from the point A. The lengths of BC, AC and AD being 101, 123 and 194, respectively, find AB and CD. Ans. 159 and 150.

11. ABC is a triangle. BD is the offset on AC. The lengths of AB, BD and BC are 89, 75 and 98, respectively. Find the length of AC. Ans. 111.

12. The base and the perpendiculars of a trapezoid are 256, 135 and 196, respectively. Find the fourth side. Ans. 263.

13. The two offsets in a trapezoid are 114 and 82. The perpendicular distance between them is 95. Find the length of the fourth side. Ans 100.

14. The base, the side opposite the base and one of the perpendiculars of a trapezoid are 364, 407 and 169, respectively. Find the other perpendicular. Ans. 351.

15. The two perpendiculars and the side opposite the base of a trapezoid are 402, 259 and 379, respectively. Find the base. Ans. 351.

Chapter. IV.—Instruments required for Chain Survey.

Revenue survey treats of marking out the boundaries of lands measuring and mapping them and finding their area. The marking of the boundaries of properties called *demarcation* is dealt with in Chapter V. Field measurement is treated of in Chapters VI and VII. The principles of mapping and of computing areas are described in Chapters VIII and IX, respectively. How to replace missing field-stones and measure new sub-divisions in a surveyed field are explained in Chapters X and XI, respectively.

2. The measurement of straight lines is made with *Gunter's chain.* In addition, the following instruments are used for measuring angles :— *Cross staff*, *Plane Table*, *Prismatic Compass*, *circumferenter and Theodolite.* For the simple operations described in this manual, the only angle with which we are concerned is the right angle and that is measured or formed on the ground with the cross-staff.

Gunter's chain and its construction.

3. Gunter's chain (see Fig. 20) called after the name of its inventor is an instrument used for measuring the distances in a survey. It is made of strong iron or steel wire with a brass handle at each end by which it can be dragged along the ground. It is 66 feet or 22 yards long divided into 100 equal divisions called links. Each link comprises one long piece of wire and also one or more small rings attached thereto. A link is equal to 7 $\frac{92}{100}$ inches or nearly one span in length. The rings are not riveted and can be removed or more added when necessary. The brass handle at each end is included in the length of the last link.

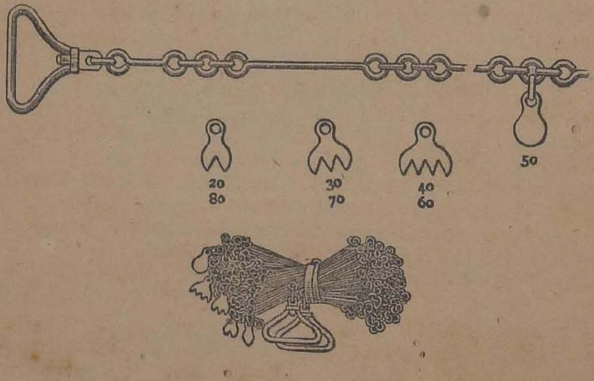


Fig. 20.

In the middle of the chain at 50 links from each end, there is a brass disc. At 10, 20, 30 and 40 links from each end of the chain, there are other brass discs with 1, 2, 3 and 4points respectively, to enable the surveyor to readily count the number of links. Thus the brass indices for 10 and 90 have one point, those for 20 and 80, 2 points, those for 30 and 70 three points, while those for 40 and 60 have four points.

Arrows.

Fig. 21.

4. Each chain is provided with ten (Fig. 21) *arrows* made of stout iron wire about a foot long. They are pointed at one end so as to be easily thrust into the ground. The other end of the arrow is curled into a ring to serve for a handle. The arrows are used for counting the number of chain lengths in a line.

Method of measurement.

5. To find the distance between two points such as the corners of a field, measurement is made in a straight line from one to the other. When the ground is sloping, the *horizontal* distance must be measured and not the distance along the ground (see paragraph 8 below). The point from which the measurement begins is called the starting point, and the other end of the straight line to be measured is called the closing point. A flag should be placed upright at each of these points. If the distance to be measured is very long, intermediate flags should be placed so that the chain may not deviate from the line required.

Duties of the leader, the follower and the surveyor.

6. Two men are required to use the chain—one who drags the chain forward called *the leader* and the other the *follower*. The follower holds a handle of the chain with his left hand and stands over the starting point. The leader takes in his left hand the other handle and also the ten arrows with their heads turned to his right and proceeds in the direction of the closing point. When a chain's length from the starting point has been reached, he turns back and faces the follower, who then signals to the leader to move to his right or left until the chain is exactly in a straight line between the starting and the closing points. Both men then stoop down and hold the chain quite straight, the handles touching the ground. The surveyor should take up his position behind the follower, check the line and watch the chainmen carefully. He should see that the chain is properly stretched, that it is neither too tight nor too loose, and that there are no knots in it. The leader takes an arrow with the right hand and sticks it vertically into the ground at the end of the chain, touching the outside of the handle. If the ground is too hard to admit of the arrow being thrust in, the leader makes on it a cross mark thus + with the sharp point

of the arrow, and lays it on the ground so that its point may touch the centre of the cross. Both men then stand up and swing the chain a step to either the right or the left to avoid disturbing the arrow and walk in the direction of the closing point. When another chain's length is measured, the follower reaches the first arrow, and holding the chain handle and the arrow together again directs the leader to the right or the left. The leader also checks the position of the follower by seeing that the latter is in a line with the flag at the starting station and puts down another arrow. When the third chain is measured, the follower picks up the second arrow and so on until he reaches the tenth arrow. He then accurately marks the position of the tenth arrow on the ground and returns the ten arrows to the leader before the measurement of the eleventh chain begins. The surveyor should note in his field note-book "1,000" when ten chains have been measured. When the leader reaches the closing point, he pulls the chain tight from the last arrow to the closing point.

Reading off links.—The surveyor then reads off the number of links on the chain by looking at the brass indices and counting the links. The total distance measured will be made up of (1) as many thousands of links as there were changes of arrows; (2) as many hundreds of links as there are arrows in the hands of the follower; and (3) as many odd links as are read off on the chain between the last arrow and the closing station.

For example.—Suppose the follower has returned the arrows 5 times and has 7 arrows in his hand and the 47th link is on the closing station. The distance measured is 5,000 links + 700 links + 47 links = 5,747 links.

To check the number of arrows with the follower, the surveyor should count the number in the hands of the leader. He should do this frequently in the course of measurement to satisfy himself that no arrow is dropped carelessly by the follower or the leader.

Exercises in Reading Links.

1. The follower returned the arrows thrice and has 9 arrows in his hand and the distance between the last arrow and the closing station is 58 links. Find the entire length of the line. Ans. 3,958 links.

2. The leader had in his hand 7 arrows after they were changed 6 times and the last chain in the measurement was deficient by 39 links. What was the total distance measured? Ans. 6,361 links.

3. The distance measured between two stations is 25,496 links. How many times were the arrows exchanged? Ans. 25 times.

How many arrows had the leader in his hand at the closing station and what was the distance between the last arrow and the closing station? Ans. The leader had in his hand 6 arrows, and the distance between the last arrow and the closing station is 96 links.

Where the closing station or both the closing and starting stations become invisible after a certain length.

7. It sometimes happens that in the course of measurement the closing station becomes invisible after a certain length. The follower cannot therefore direct the leader. The latter should then fix his position in the line with reference to the starting station. Where the starting station also becomes invisible, the surveyor should plant flags at either end of the chain wherefrom it was last visible and the leader should find his position with reference to them.

Measurement on slopes.

8. It should be clearly borne in mind that the distance to be measured between two stations is horizontal and not the actual distance along the surface. When therefore the ground is uneven, the process described hereunder should be followed—*vide* Fig. 22.

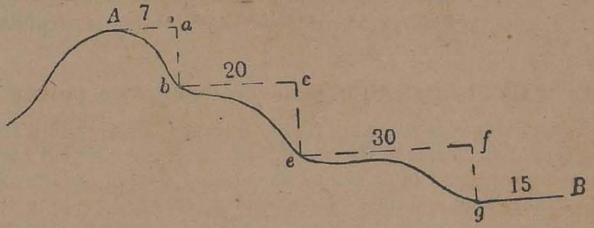


Fig. 22.

Descent.

9. In descending a slope, the follower should hold one end of the chain at the starting station. The leader should hold a convenient part of the chain raising it a few feet over the ground on which he stands so as to keep it as nearly as can be judged horizontal. Holding the point of an arrow in the other hand, he should drop it vertically, making a mark on the ground where the arrow falls. He should wait till the follower reaches him, taking care not to let go the point in the chain at which he dropped the arrow. The follower then takes charge of the chain at the same point and the process is repeated as often as necessary till the bottom of the slope is reached.

The sum of all these horizontal distances will be the total horizontal distance of the slope. This process is called "stepping" or "levelling" or "breaking" the chain. In figure No. 22, the process described above was repeated three times and the total horizontal distance between A and B is 72 links.

Ascent.

10. In ascending a slope a very similar process is performed. The follower holds one end of the chain vertically over the starting station at a convenient height and directs the leader who goes some distance up the slope until the chain or a portion of it is stretched horizontally. He then drops a pebble vertically over the starting station. If the pebble falls exactly in the middle point of the station, he instructs the leader to make a mark on the ground. If not, he signals to him to draw up or give in the chain until the pebble falls on the correct point. This process is repeated until the whole slope is measured. It is much easier to measure down, than to measure up a slope.

Running chain over prickly-pear and such other obstructions.

11. Sometimes an obstruction less than a chain in width is met with in the line of measurement such as a well or a bed of prickly-pear. When he arrives at the edge of it, it may happen that the leader cannot

reach the spot where an arrow is to be placed. In such cases he should fix it in the ground as near the obstacle as is convenient, the surveyor noting at what point in the length of the chain it falls, so that he may afterwards subtract the deficiency from the total distance. From this point the chain can generally be easily stretched over or across the obstruction thus avoiding the necessity to employ one of the more or less troublesome methods of measuring round obstacles explained in Chapter VII.

To walk in a straight line between two points.

12. Sometimes it is necessary for the surveyor to walk in a straight line between two points. He should fix upon some object such as a tree or a stone in front of or behind the closing station, so that it and the object may be in one line. He should go forward keeping the two objects in line. To walk in a direct line, it is always necessary to be guided by two objects.

To trace a line in the direction of two distant points.

13. When a straight line is very long, it is sometimes necessary to get into the line without sending a man to either end to give the direction. Two men should stand in about the line at a distance of 2 or 3 chains from, and facing each other. Then by alternately motioning each other to move right or left, they soon get exactly into the line.

Testing chain.

14. The length of the chain should be tested daily before measurement begins. For this purpose, select a level piece of ground and stretch the chain moderately tightly over it. Straighten the links that are bent and fix two stout wooden pegs at each end in the handle of the chain. Take an *offset pole* (for description see *infra*). Measure the chain carefully with it making a scratch in the ground for every length of it. If the chain is too short, add one or more rings, a few of which, made by the village blacksmith, should be kept in stock. If the chain is longer than 66 feet, remove one or more rings from it. In either process, if there are several rings to be added to or removed from the chain, care should be taken to see that all of them are not added to or removed from one portion of the chain only thereby making that part unduly long or short. It should be seen that the correction is distributed uniformly throughout the chain at least in the two halves of it. One of the wooden pegs should be shifted to suit the chain as corrected. If the pegs are allowed to remain permanently in the ground, the chain need only be put upon them in order at any time to test its correctness.

Why a chain of 66 feet is used for revenue survey and not one of hundred feet.

15. In all surveys for revenue purposes, Gunter's chain of 66 ft. is used as it facilitates the conversion of square links into acres and cents. Thus one chain = 100 links or 66 ft. One *square* chain therefore = 100 × 100, that is, 10,000 square links, or 66 × 66 which is 4,356 sq.

ft. So ten square chains (10,000 × 10 = 100,000 square links or 4,356 × 10 = 43,560 sq. ft.) are equal to one acre, and one cent ($\frac{1}{100}$th of an acre to 1,000 square links.

The area of a field measured with Gunter's chain is thus obtained by dividing the total number of square links by 100,000 to find acres or by 1,000 to find cents.

For other purposes, such as Engineering works, where it is more convenient to keep the results obtained in yards and feet, another chain (100 links = 100 ft.) is used. One acre measured with this chain contains 43,560 square links which is not so simple a number to deal with as 100,000. This chain is therefore never used for a Revenue Survey.

Fig. 23.

Cross-staff—Construction of.

16. The cross-staff (Fig. 23) consists of a piece of wood called the *head*, 4″ square and 2½″ thick, and the *staff*—an iron rod ⅝″ in diameter and 4½ feet long, which screws into the underside of the head and is sharply pointed at the other end so that it can be stuck into the ground. On the upper surface of the head two grooves are cut with a saw half an inch deep, and at right angles to each other, crossing in the centre.

The use of the cross-staff—First use—Measuring a right angle from the chain line to an object.

17. The cross-staff is used for two purposes—(*a*) for measuring a right angle from the chain line to an object, (*b*) for setting off a right angle from the chain-line to a spot where it is proposed to fix an object. For the first purpose, it is inserted in the ground, at that point in the chain line where, when one groove is directed to the forward (or back) station, the other points to the object to the right or left of the line.

The chain-line is read off and the distance from the object to the cross-staff measured. The relative position of the object to the chain line can then be exactly reproduced upon paper.

Second use—Setting off a right angle from the chain line to a spot where it is proposed to fix an object.

18. To find a spot at a given distance from a point in the chain-line and at right angles to it, plant the cross-staff at the given point in the chain-line, and direct one groove to the forward or back station. Looking through the other, send a man towards, and by a rough guess beyond the spot you are endeavouring to find, and signal to him to move to the right or left until you see him exactly in the centre of the groove. The given distance is now measured from the cross-staff towards the man and thus the proposed situation of the object is correctly determined. This is a reversal of the first method, since we reproduce on the ground what has already been measured and plotted upon paper.

Hints to be observed in the use of the cross-staff.

19. The following hints should be carefully observed. Plant the cross-staff *upright* in the ground, so that it does not incline in any direction. When the forward or back station has been sighted through one groove, the staff must not be held or touched while observing the right-angle. If the ground is very hard, observations may be made by two men, who must look through the grooves simultaneously, and the cross-staff may be held by one of them. Always check the correctness of the chain-line by sighting *both* forward and back stations.

Offset—Why long offsets should not be taken.

20. The distance between the cross-staff and an object, when a right angle to it has been formed, is called an *offset*. An offset is the shortest measurement between the object and the chain-line. Offsets should not be taken to objects which are situated more than three chains from the chain-line, as it is impossible to use the cross-staff accurately beyond that distance. If an object be at a greater distance, its position must be fixed by two lines to it from convenient points in the chain-line, the distance between them forming the base of a triangle, with the object at the apex. The triangle should be well-shaped so that it may plot correctly. The lines are called *oblique* offsets (Fig. 24).

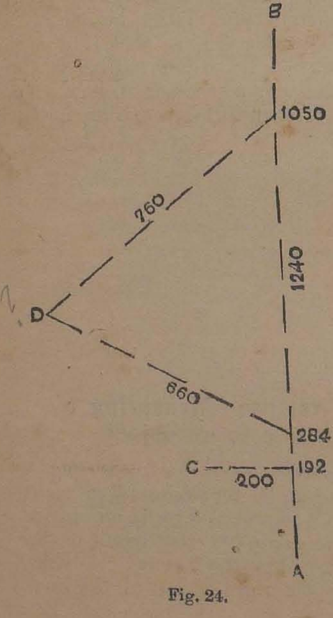


Fig. 24.

Why a right angle is formed on the ground.

21. It is hardly necessary to explain that the grooves on the cross-staff might be cut to form any angle with each other. A right angle is however chosen because it can be accurately laid out on paper with such simple means as the scale and bit. Other angles require special instruments, and even then cannot be so correctly plotted. A right angle also assists in the calculation of areas by a simple process of arithmetic which will be explained in Chapter IX.

Testing the cross-staff.

22. To test the correctness of the cross-staff, sight a distant object through one groove and direct a flag at a distance of about 2 chains from the instrument to move until it is duly intersected along the second groove. Then turn the cross-staff round until the distant object is sighted along the groove through which the flag was sighted. If the flag is now correctly intersected along the other groove the instrument is correct. An incorrect cross-staff should not be used.

Offset Pole—Construction and use of.

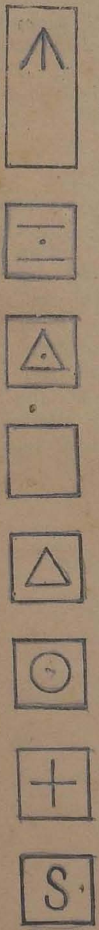
23. Offsets being invariably short distances are generally measured not by the chain but by a pole called the Offset Pole (Fig. 25). It is a straight piece of bamboo or wood an inch and-a-half thick, and ten links long with lines marked at every link. Its extremities are shod with brass or iron. The offset pole is placed flat on the ground with one end touching the starting station, and with the other end pointing towards the closing station. It is turned over and over, care being taken to keep it in a straight line between the two points, until the closing station is reached. The number of times the pole is turned over gives the number of tens of links measured. This together with the odd links read on the pole at the closing station gives the total offset distance measured.

Fig. 25.

Chapter V.—Demarcation.

Demarcation is the marking out of the boundaries of properties. It may be done by raising hedges, forming bunds or planting stones or other durable marks, but is done in the Madras Presidency by means of stones of durable quality, roughly squared, and of the following descriptions :—

i. *Theodolite stones.*
ii. *Field stones.*
iii. *Sub-division stones.*



Side view of demarcation stone.

Top view of a theodolite bijunction stone.

Top view of a theodolite trijunction stone.

Top view of a field stone.

Top view of a khandam trijunction stone.

Top view of a khandam bijunction stone.

Top view of a boundary offset stone.

Top view of a sub-division stone.

Fig. 26.

2. *Theodolite stones* are the marks placed at stations where a theodolite has been set up. Their dimensions are 3 feet × 9 inches × 9 inches with a plummet hole cut on the top and a broad arrow on one side. Their position is marked on the village maps and on the block sheets where such exist. In districts that have been resurveyed however, all the theodolite stations fixed at the original survey were not marked on the resurvey map. Theodolite stones at the trijunctions of three villages are built into masonry bases of stone and mortar, 2½ feet × 2½ feet × 2½ feet, which should be buried in the ground to the depth of 2 feet, and the theodolite stone should be embedded to the depth of 2½ feet.

3. *Field stones* comprise—

(*a*) Field stones proper, viz., the marks placed at the bends and field trijunction points on the boundaries of survey fields. These points are shown as demarcated in the Field Measurement Books;

(*b*) The marks placed at khandam and plane-table stations. These points are marked in the village maps and block sheets.

Their dimensions are 2 feet × 6 inches × 6 inches with a broad arrow cut on one side. Field stones [class (*b*)] which demarcate blocks or khandams are distinguished by a circle or a triangle cut on the top, while those which were offsetted from the lines joining theodolite stations were marked with a cross (+). The latter, known as 'boundary offsets' however, will in future be discontinued.

4. *Sub-division stones* comprise—

(*a*) The marks placed at the bends and trijunction points on the boundaries between sub-divisions which are registered differently in columns 5, 6 or 8 of the village register A. These points are shown as demarcated on the map of the survey field in the Field Measurement Books.

(*b*) The marks placed at such other points on the boundaries of sub-divisions as the Government may order in each district or taluk. These points are not shown as demarcated in the Field Measurement Books.

The dimensions of sub-division stones are also 2 feet × 6 inches × 6 inches with the broad arrow cut on one side, but they are distinguished from field stones by an "S" cut on the top.

5. In South Canara the stones set up at the bends and trijunctions on the boundaries of sub-divisions which form part of fields known as "hill numbers" are of laterite roughly squared of dimensions measuring 2 feet × 9 inches × 9 inches marked with a broad arrow cut on one side.

6. In the Wynaad taluk of Malabar district and in the Nilgiris outside the Municipal towns, stones of the descriptions mentioned above need not be squared but should approximate as nearly as practicable to the prescribed dimensions.

7. The broad arrow mark cut on all stones should be at least 2½ inches long and a quarter of an inch deep.

Chapter VI.—Field Measurement.

Preparation of a rough hand sketch.

After the completion of demarcation, the surveyor should walk over the ground to be measured for the purpose of obtaining a general knowledge of the surface. A rough sketch of the field should be prepared showing all bends and in it should be marked the positions of the trijunctions of adjoining fields and the most conspicuous objects, such as wells, houses, temples, roads and streams. The following instructions should be borne in mind in the preparation of the rough sketch. The north point should always be indicated first. It is sufficient to make the top of the paper the north whenever possible. The surveyor should start from a corner of the field say the north-west or north-east and proceed round the field keeping always to the same direction, either right or left. As he goes, he should send a man in advance to the next stone. He should then walk towards the man counting his paces as he goes. This will give him the approximate distance between the two stones, 25 paces being ordinarily equal to a chain. He should next determine roughly the length of the line to be drawn by him on paper for the distance paced by him and should accordingly draw the line between the first and the second stations. This process should be repeated at each stone until the starting station is reached. Before proceeding to measure the lines with the chain, the surveyor should draw on the sketch all such lines as it will be necessary to measure to enable the field to be plotted upon the principles explained hereunder.

Note.—The above procedure applies to the survey of isolated fields in surveyed tract. In initial survey, the demarcation sketches should be drawn as the demarcation progresses.

Triangulation.

2. A triangle is a simple geometrical figure that has always a definite shape and size if the length of its sides are known. See Figure No. 8. Its shape can always therefore be correctly drawn on paper. An irregular four-sided field on the other hand is not determinate in shape and size if only the length of its sides are known. The following diagram (Fig. 27) shows how such a field may be made to assume different shapes and gives different areas. To define the shape of the field therefore and to plot it correctly, we should divide it into triangles. This is done by measuring a diagonal from one corner to another opposite to it. In this way, a field of any number of sides can be divided into triangles. Thus (Fig. 28) two triangles are formed in a field of four sides; three triangles in a field of five, four in a field of six and so on. The number of triangles accordingly into which a polygon can be divided is equal to the number of the sides of the polygon *minus* two.

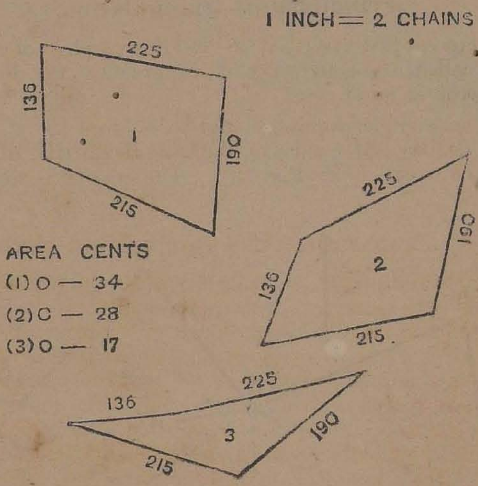
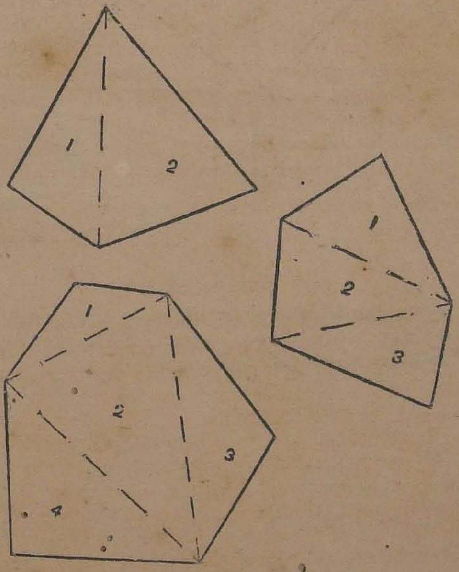

1 INCH = 2 CHAINS
225
136
1
190
215
AREA CENTS
(1) 0 — 34
(2) 0 — 28
(3) 0 — 17
225
190
2
136
215
225
136
3
190
215

Fig. 27.


1
2
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2
3
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2
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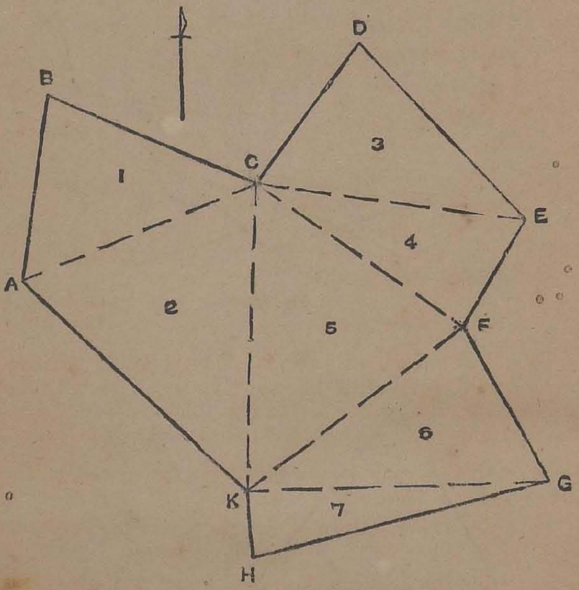
4

Fig. 28.

Principles of triangulation.

3. The process just described of dividing a piece of land into triangles, is called *triangulation* and in practice the following rules should be borne in mind :—

(1) The triangles formed should be as large and well-conditioned as possible, *i.e.*, the three sides of the triangle formed should as far as practicable be equal—(*vide* Fig. 29). The reason is that in plotting



Number of sides 9. *Number of triangles* 7.

Fig. 29.

the field, large and well-formed triangles ensure greater accuracy of shape than small or badly shaped ones. In the figure, ABC, CDE, ACK and CKF are well-conditioned triangles.

(2) Diagonal lines should not cross each other—(*vide* Fig. 30) which shows how they should *not* be drawn.

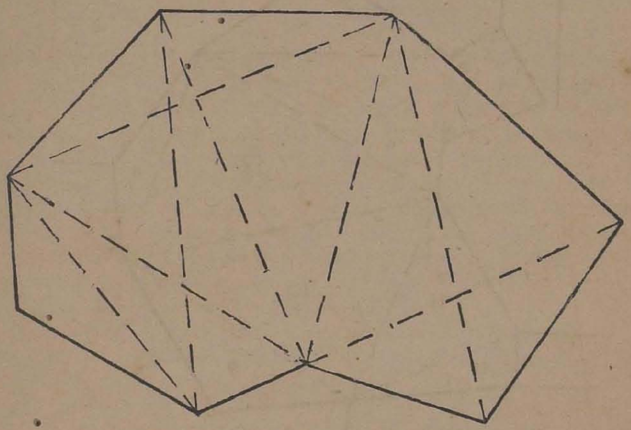


Fig. 30.

(3) To satisfy himself that no quadrilateral is left untriangulated, the surveyor should see that in the whole figure as many triangles are formed as there are sides, *minus* 2. In Fig. 29, the field consists of nine sides; the triangles obtained are therefore 9 *minus* 2, *i.e.*, 7.

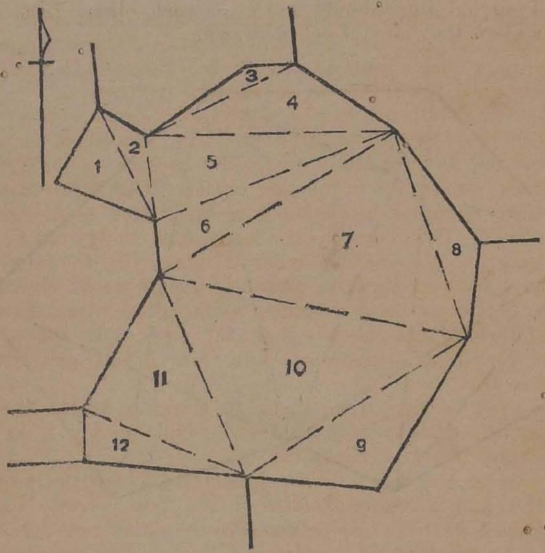
4. Based on these principles, two methods are generally employed for measuring fields. They are—

(1) To divide the field into a number of small triangles making each side of the field generally the base of a triangle.

(2) To divide the field into fewer but larger triangles whose sides are the lines joining trijunction points only; minor bends are offsetted from these lines.

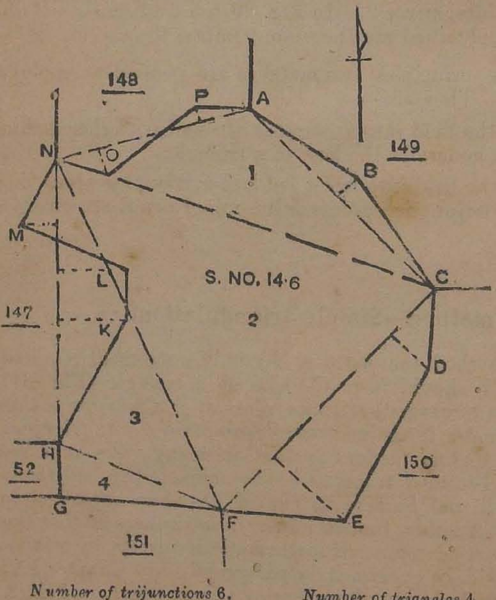
First method—Simple triangulation.

5. For the first method the chain is the only instrument required. Each side of the field should form the base of a triangle (Fig. 31). It sometimes happens however that a quadrilateral or a polygon is thus formed in the interior, but it again should be sub-divided into triangles. The chief objection to this method is that in many cases it is not possible to secure well-formed triangles. The shape of the field therefore when plotted, will not be true to fact, as has been explained in paragraph 3 *supra*. Another, though minor, disadvantage is that the area of the field cannot be computed mathematically except by a laborious process which will be explained in paragraph 11 of Chapter IX. Moreover it often involves the measuring of a large number of lines. The process to be described next is therefore generally preferable.



Number of sides 14. *Number of triangles* 12.

Fig. 31.



Number of trijunctions 6. *Number of triangles* 4.

Fig. 32.

Second method —Triangulation and offset.

6. To carry out this method, both chain and cross staff are used. The process is as follows (see Fig. 32):—

(1) Start from a trijunction, generally in the north-east corner of the field, and proceed round the field keeping always to the same direction, either right or left. Draw a straight line from the first tri-junction to the next, and

mark offsets on it to all the field bends situated on either side of it. Then draw a straight line from the second to the next trijunction and similarly mark offsets from it to all the field bends on that line. Repeat the process until you return to the starting trijunction.

(2) The field bends can be plotted on their respective "diagonal" lines when they have been offsetted. Eliminate them therefore from your view and fix your attention for the present on the figure formed by the lines joining the trijunction stones. This figure must now be divided into triangles to enable it to be plotted as though it were a separate field. Considerable care is required to lay out the triangles so as to take in the greatest number of offsets with the fewest lines, to make the offsets as short as possible, and to avoid obstacles. You will thus obtain as many triangles as there are trijunctions *minus* 2.

The following example will make this clear: In the field sketched in figure No. 32 draw a straight line from A to C and from it draw an offset to B.

Next draw a line from C to F marking offsets to D and E. There are no offsets to be marked on the line joining F and the next stone G which is also a trijunction.

The same is the case with the line GH. The next line is from H to N, K, L and M being offsetted on it. Lastly draw NA offsetting O and P and we have now returned to the starting station A.

Triangles are formed by joining CN, NF, FH, thus making four triangles as there are six trijunction stones.

(3) If a field bend stone is fixed from a diagonal line by a long offset, an additional offset should be measured from it to the nearest diagonal. (See Fig. 33.) A, having been fixed on the diagonal BC by a long offset, has also been offsetted on BD, the nearest diagonal.

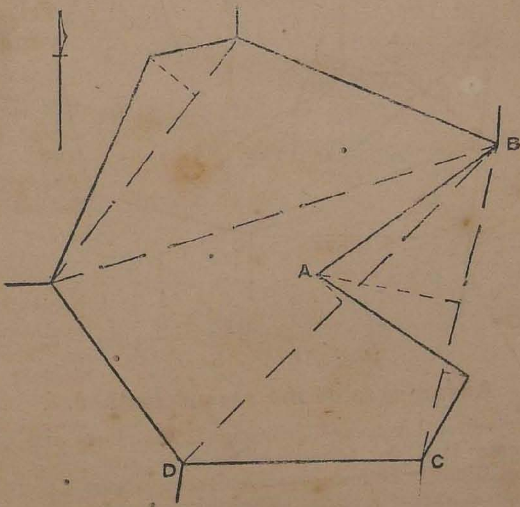


Fig. 33.

(4) If it is required to calculate the area of the field by the offset and base process (*vide* paragraph 6 of Chapter IX), an offset should be measured in each triangle for this purpose. (See Fig. 34.) Thus in the triangles BCD, ABD, and AED, offsets have been taken to the points C, D and E from the bases BD, AB and AD, respectively. This is however rarely necessary in practice.

(5) If any of the triangles formed is ill-conditioned (*i.e.*, the shortest side is less than half the longest side of the triangle), the vertex should be offsetted from the base, so that the offset can be used for plotting the triangle.

(6) The above rules provide for the triangulation of all trijunctions to enable survey fields to be plotted together to make up a combined map. In maintenance, it is often unnecessary to triangulate with this object in view; and hence, it is often sufficient to form well-conditioned triangles by lines joining trijunction points not necessarily adjacent and to offset trijunction points not so joined (together with other field bends) on the sides of the triangles so formed.

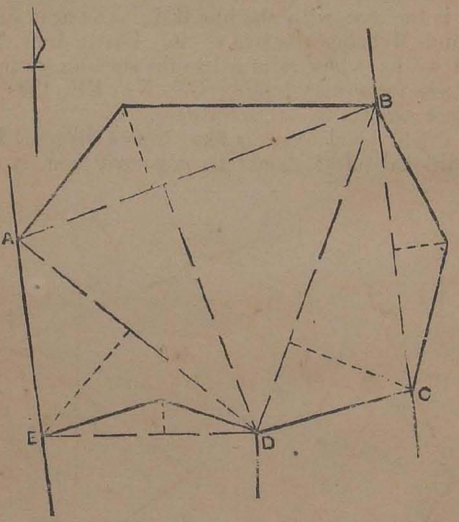


Fig. 34.

Advantages of the second method.

7. (1) As minor bends are determined by offsets and only the principal points fixed by triangulation, large and well-conditioned triangles can ordinarily be formed, which ensure accurate plotting.

(2) Suppose survey number 147 adjoins survey number 146 as in Fig. 32. The straight line from H to N and the offsets on that line to the stones K, L and M need not be remeasured for survey number 147, as they have been already measured for survey number 146. This saves a good deal of time and labour.

Process of measurement.

8. After drawing all the straight lines requisite for plotting the figure, the surveyor should first measure the boundary lines technically called 'F' lines. Diagonal lines (or "G" lines) should then be measured from one trijunction to another and offsets, if any, taken to bends as the work proceeds. The point in the diagonal line at which the offset falls (technically called the chain distance) should also be noted.

Recording of measurements.

9. All measurements, names, etc., recorded in a plan or sketch should be written so that they may be read from one position without having to turn the map round. The only exception admissible is in the case of chain distances and offset measurements which should be entered in the same direction as the measurements were taken. (See Fig. 35.)

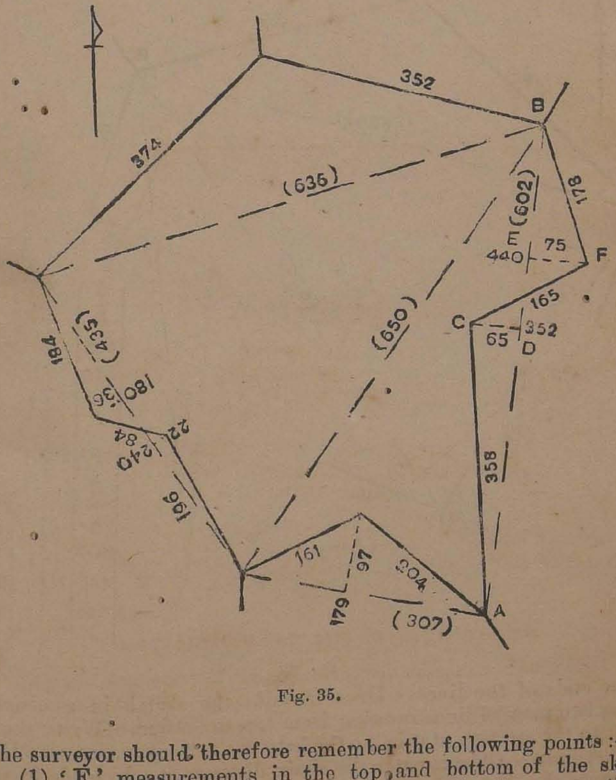


Fig. 35.

The surveyor should therefore remember the following points :—

(1) 'F' measurements in the top, and bottom of the sketch should be entered immediately over and under the lines respectively outside the field so that they may be read from left to right. 'F'

measurements in the left and right of the sketch should also be entered immediately over or under the lines respectively outside the field so that they may be read from bottom to top.

(2) Measurements of 'G' lines should be entered in the same manner, but the figures should be enclosed in brackets.

(3) Measurements of *offsets* and *chain distances* should be entered as follows:—

The *chain distance* is written at that point in the G' line from which the offset is taken; a dotted line is drawn to represent the offset and its measurement is entered immediately above it. The chain distance is always read from the starting station.

(4) If the space in the sketch does not admit of chain distances and offset measurements being entered, they should be recorded in the manner indicated in diagram No. 36. Alphabetical letters are given

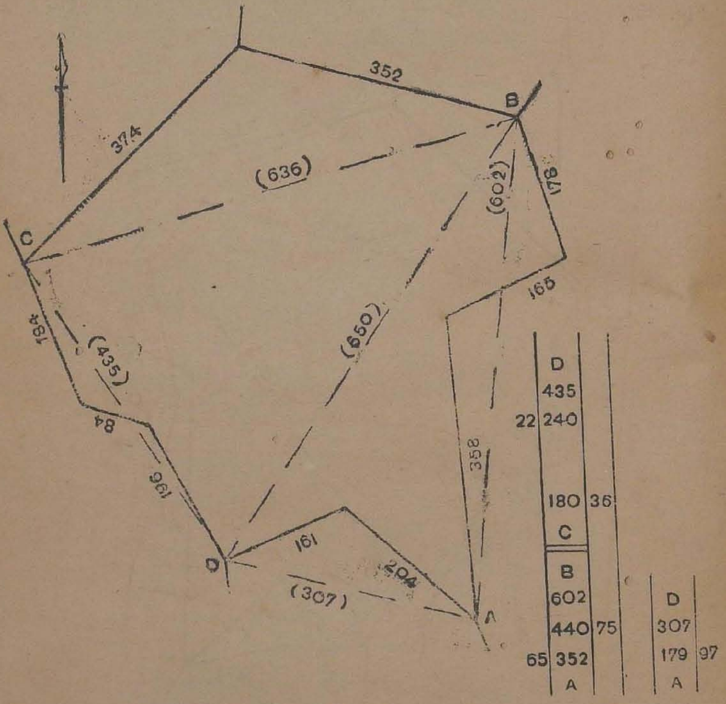


Fig. 36.

to the ends of the lines. Draw outside the sketch in a convenient corner two parallel lines running from top to bottom. Write the letter given to the starting station at the bottom of the space between the two parallel lines. Over it enter the chain distance at which the first offset is measured. Enter the offset distance to the right or left of the chain distance outside the parallel lines according as the stone offsetted is to

the right or left of the line along which you are proceeding; when all the bends are offsetted, enter the total distance of the diagonal over the last chain distance and over that enter the letter indicating the closing station. As many sets of parallel lines are drawn as are necessary.

Recording of details.

10. A "detail" is a conspicuous object of a permanent character in a field which it is necessary to mark in the map, such as a house, well, temple, channel, burial-ground, or road. Details should be recorded by taking offsets from the nearest 'G' line to a few prominent points in them such as corners in the case of a house, bends in the case of roads or channels (Fig. 37). In the case of roads, cart-tracks, foot-paths,

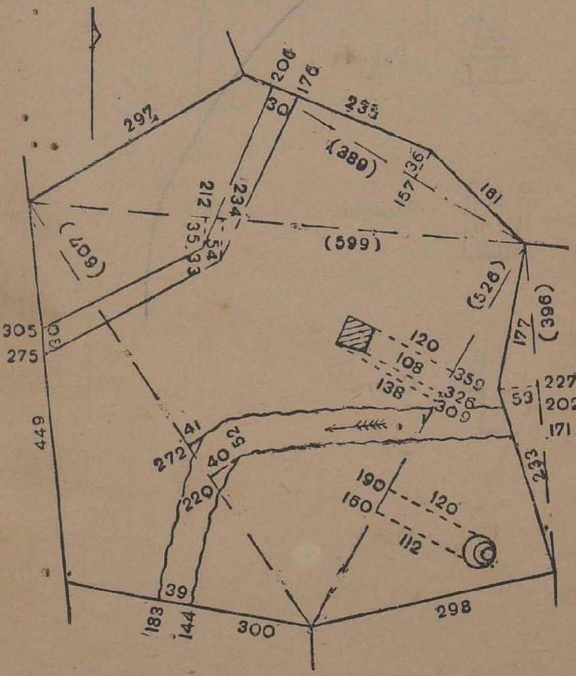


Fig. 37.

channels, etc., the distance in the 'F' lines at which they enter and leave the field and their width at important bends should be recorded. In the case of channels, the direction of the current should be indicated by an arrow. The conventional signs which are generally used for denoting details are given in Fig. 38.

1 KANNANUR Parent village.

2 Adanur Hamlet.

3

or House.

4

5 Pagoda.

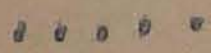
6 Mosque.

7 Church.

8 Fort.

9 Lamp post.

10 Lighthouse

11  Footpath.

12 Cart-track.

13 Earthen road.

14 Gravelled road and mile stone.

15 Metalled road and mile stone.

16 Railway.

17 Telegraph.

18 River, canal and aqueduct.

19 River and stream with anicut.

20 Culvert and bridge.

21 Ferry.

22 Tank.

23 Permanent calingula.

Temporary do.

24 Permanent sluice.

Temporary do.

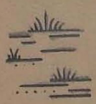
25 Square well.

26 Round well.

27 Indigo vat.

28 Fountain.

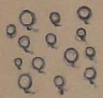
29 Hydrant.

30  Swamp.

31 Salt pan.

32 Sand.

33 Burial or burning ground.

34  Scrub and jungle.

35 Limit of rocky ground.

36 Hill.

37

Lambton's G.T. Survey station and height in feet above sea level.

38

Modern Series do.

39

Madras Survey do.

40		Village boundary station.	
41		Khandam station.	
42		Minor circuit station.	
43		Theodolite station.	Town survey
44		Chain survey stone.	Town survey
45		Field stone.	Town survey
46		Rock mark.	
47		Forest cairn or pillar.	
48	———	Village boundary.	
49	———	Survey field boundary.	

Correcting mistakes due to measurement with a wrong chain.

11. If after completing the measurement of a field, it is found that an incorrect chain was used, it is not necessary to remeasure all the lines with a correct one. The lengths already recorded may be corrected as follows :—Suppose the measurement of a line is recorded as 800 links with a chain one link too long. The distance obtained is obviously shorter than the true distance by 8 links. If 800 links is recorded with a chain one link too short, the distance obtained is greater than the true distance by 8 links. In the former case the correct distance should be 808 and in the latter 792 as shown below :—

$$\frac{\underset{\text{Links}}{\overset{\text{Length of the incorrect chain.}}{101}} \times \overset{\text{Incorrect distance.}}{800}}{\underset{\text{Length of the correct chain.}}{100 \text{ links}}} = 808;$$

$$\frac{\overset{\text{Length of the incorrect chain.}}{99} \times \overset{\text{Incorrect distance.}}{800}}{\underset{\text{Length of the correct chain.}}{100}} = 792$$

It therefore follows that the correct distance is obtained from the following proportion :—length of correct chain : length of chain used : measured distance : true distance ; or in other words, multiply the incorrect distance by the length of the incorrect chain (*i.e.*, the chain used) and divide the product by the length of the correct chain. The figure representing the length of the chain both in the multiplier and the divisor should be of the same denomination, *i.e.*, if the multiplier is in links, the divisor should also be in links ; if the former is in feet, the latter should also be in feet and so on.

Exercises.

1. A straight line was measured with Gunter's chain. The chain subsequently found to be four links too long gave a length of 8,976 links. What is the correct distance? Ans. 9,335.

2. The measurement from A to B taken with a Gunter's chain is 9,765 links. The chain was afterwards found to be $1\frac{1}{4}$ feet too short. What is the true length of AB? Ans. 9,580.

3. The distance of a G line measured with a hundred feet chain is 8,670 links. The chain was found to be $1\frac{1}{2}$ feet too long. What was the correct distance in feet? Ans. 8,800.

4. In exercise No. 3, reduce the correct distance to Gunter's links. Ans. 13,333.

5. The distance between two places measured with an incorrect Gunter's chain which was 6 inches too short, was found to be 3 miles. Express the correct distance in miles, furlongs, yards, feet and inches. Ans. 2 miles 7 furlongs and 180 yards.

6. In measuring a field, the following diagonal and offset measurements were recorded. The chain was subsequently found to be $3\frac{1}{2}$ inches too short. Find the correct distances.

	B		*Ans.*		B	
	1827				1819	
287	895			286	891	
	786	300			783	209
	495	299			493	298
168	208			167	207	
	184	299			183	228
	A				A	

Measurement of sub-divisions.

12. Suppose the field to be measured contains two or more sub-divisions. These have also to be measured. The sides forming the boundaries of the sub-divisions should be measured first. The sub-division bends should then be offsetted on the nearest diagonal lines of the field. (*Vide* diagram No. 39.)

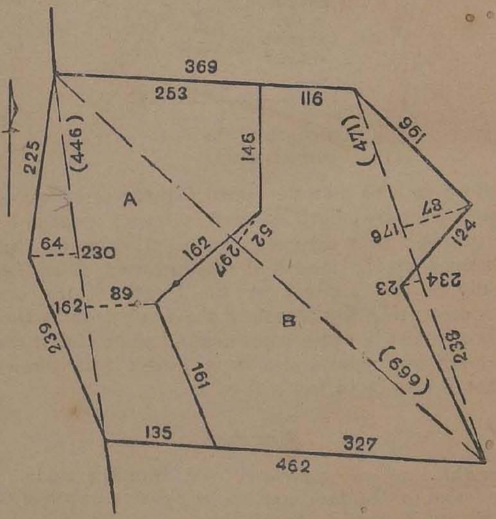


Fig. 39.

Exception to the rule of triangulation in the case of long narrow fields.

13. The system of triangulation described in paragraph 6 *supra* should be followed as a rule, but in the measurement of long narrow channels, roads and similar fields, triangulation will give ill-conditioned triangles formed on very small bases. The figure when plotted

cannot therefore be depended upon to give the true shape of the field on the ground. (See Fig. 40.)

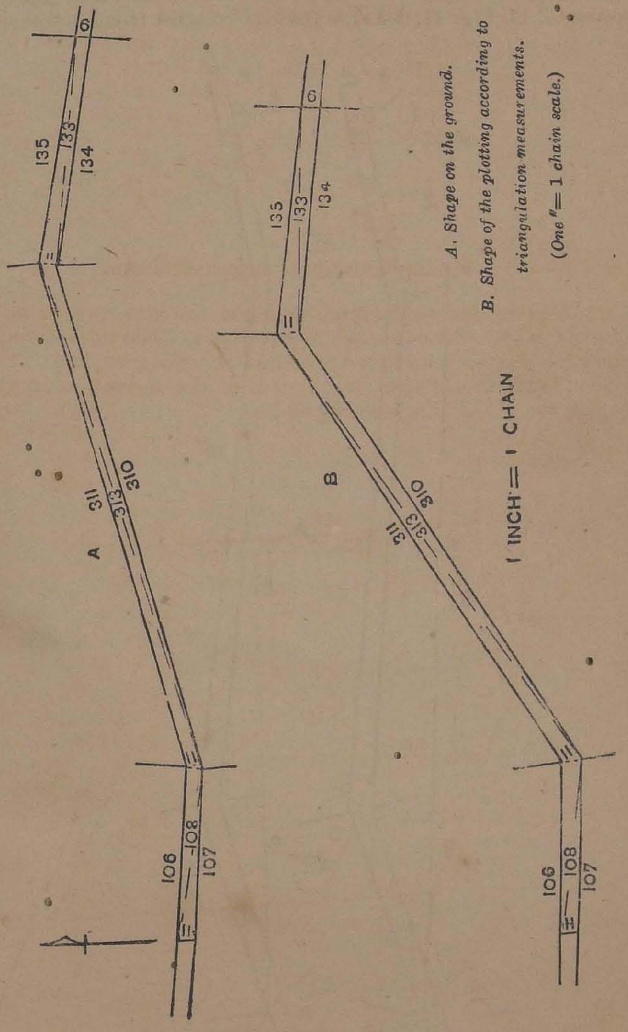


Fig. 40.

In such cases, the stones on the field boundary should be offsetted from a line drawn between two trijunctions at opposite ends of the field See Fig. 41, section A, in which X and Y are the opposite ends. If the line from X to Y is not visible or not easy to chain, a right-angled

triangle should be formed so that the line between the two trijunctions may subtend the right angle and the stones on the field boundary offsetted from the longer of the two sides which contain the right angles. In section B of Fig. 41, XYZ is the right-angled triangle formed and

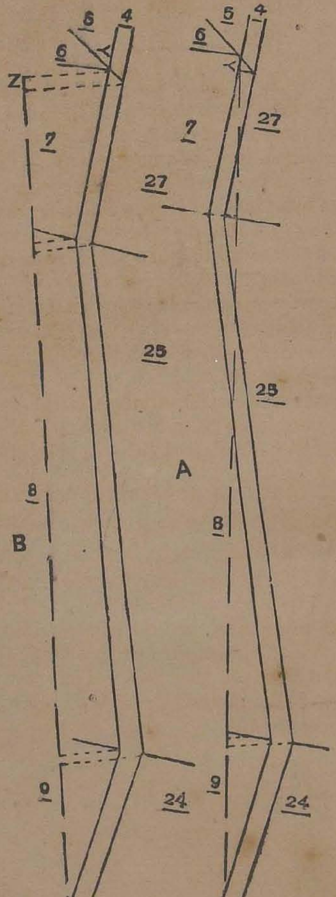


Fig. 41.

the field boundary stones have been offsetted on ZX, the longer of the two sides containing the right angle.

Note.—To facilitate the plotting of the village maps, the points X and Y should be field trijunctions, or they should each be connected by not less than three check lines with the nearest field trijunctions.

Chapter VII.—The Measurement of Obstructed Lines.

In the course of his field work, the Surveyor may be impeded by various obstacles. A line may happen to be obstructed by prickly-pear, bushes, a dense growth of trees or houses. A river or a tank broader than a chain very often lies in his way. The present chapter is therefore devoted to a classification of the several kinds of obstacles and an explanation of the methods by which they may be overcome.

2. The obstructions in a line may be divided into five classes—

(i) Both stations accessible and visible from each other but the line between not chainable.

(ii) Both stations accessible but not visible from each other nor the line between chainable.

(iii) One station accessible; the other visible but not accessible, nor the line between chainable.

(iv) Both stations inaccessible though visible to the surveyor; but the line between not chainable from his position.

(v) Measurement of obstructed lines in special cases.

Class I (*a*).—Both stations accessible and visible from each other but the line between not chainable—Construction of a rectangle.

3. Instances of the first class occur when a line is obstructed by a tank or a bed of prickly-pear. The starting and closing stations are visible from one another and are also accessible but the distance cannot be obtained by direct measurement, owing to the impossibility of the chainmen standing on the line. The best way to deal with such cases is to employ the method described below, where a line AB is to be measured across a tank.

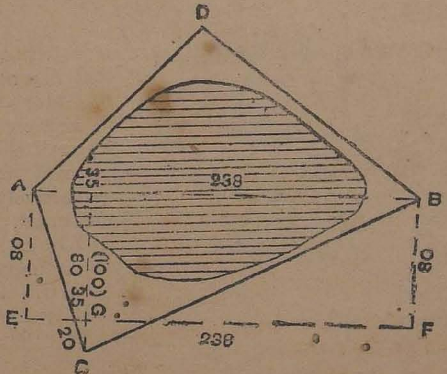


Fig. 42.

At A in the line AB (Fig. 42) with the aid of the cross-staff, set off AE perpendicular to AB, making AE any convenient length greater than the width of the obstacle, say 80 links. Similarly at B make BF perpendicular to AB and equal to AE, that is, 80 links If EF be joined, AEFB is a parallelogram with its opposite sides equal and its angles right angles, *i.e.*, a rectangle. Therefore EF is equal to AB. So by measuring EF the length of AB is obtained. To test the accuracy of the work, set up the cross-staff at E and through one groove sight A; the other should point to F. If it does not, then either AE or BF was laid out wrongly, and should be done over again.

(*b*) Measuring an offset on a line obstructed as above.

4. Suppose it is required to take an offset to stone C on the obstructed line AB (Fig. 42). Find the length of AB by forming a parallel and equal line EF in the manner explained above. On the straight line EF, take an offset to C from the point G 35 links from E, which we will suppose to be 20 links. The distance, therefore, of C from AB, which we want to find, is 20 links + the distance of EF from AB, that is, 80 links, making a total of 100 links.

If C had been 20 links to the left of EF, its distance from AB would have been 80 links — 20 links, that is, 60 links.

Class II (*a*).—Both stations accessible but not visible from each other nor the line between them chainable.

5. We may next consider the obstructions included in class II when a chain line is obstructed by houses, trees or other growth, so that the starting and the closing stations are not visible from each other. Both stations are accessible, but the line between them cannot be measured directly on account of the obstacle which also intercepts the line of vision from one to the other.

(1) Method with the cross-staff and the chain-construction of a right-angled triangle or two equal right-angled triangles.

6. (1) Suppose (Fig. 43) the line AB is obstructed by trees, so that A is not visible from B. Move the cross-staff to any convenient point C, until the grooves are directed to A and B, respectively. AC is measured, and is, say, 210 links. Produce AC to D making CD equal to AC. Then the line DB is equal to the line AB.

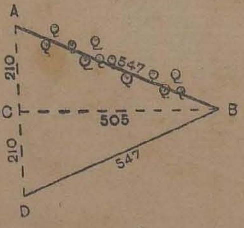


Fig. 43.

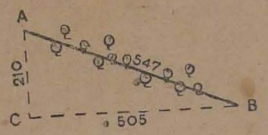


Fig. 44.

(2) Instead of producing AC to D, the length of AB can be ascertained by measuring CB which let us call 505. The angle ACB is a right angle (Fig. No. 44). So AB $= \sqrt{210^2 + 505^2} =$ 547. (See Chapter III.)

(2) A second method with the cross-staff and the chain by constructing a trapezoid on any arbitrary line.

7. At a convenient point D, say 30 links from A, set up the cross-staff and sighting A through one groove, through the other select some convenient spot X in the neighbourhood of B. Now with the cross-staff find a point E in the line DX at which BE makes a right angle with DX (Fig. 45). Measure AD, DE and EB; suppose them to be 29, 250 and 84, respectively. The figure ADEB is a trapezoid. So AB $= \sqrt{250^2 + (84-29)^2} = 256$. (See Chapter III.)

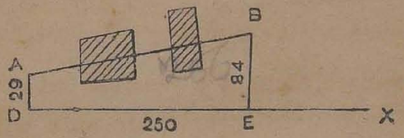
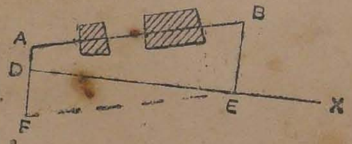


Fig. 45.

Instead of finding AB by mathematical calculation, its length may also be ascertained thus—

Make the offset AD equal to BE either by producing AD to F and making AF equal to BE (see Fig. 46), or by cutting off from BE a portion equal to AD (see Fig. 46). Then the figures ABEF and ABFD are parallelograms with their opposite sides equal. The length of AB is therefore obtained by measuring FE or FD.

Sec. I.



Sec. II.

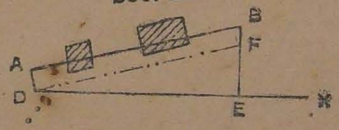


Fig. 46.

If the two ends of the obstructed line cannot be offsetted on one arbitrary line, they may be offsetted on two or more lines taken at right angles to each other. In figure No. 47 the total length of the base of the trapezoid formed is made up of CD and EF drawn parallel to each other; one perpendicular is AC and the length of the other is made up of DE and FB.

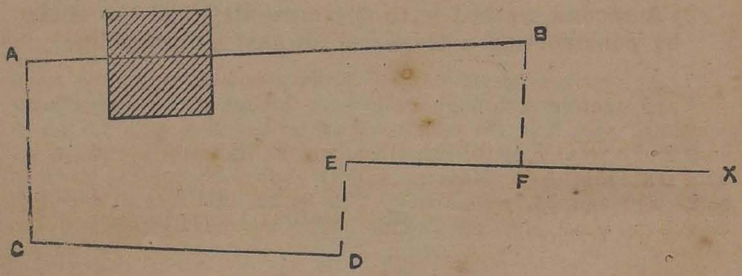


Fig. 47.

(3) A third method with the chain only without the cross-staff—Construction of two equal triangles.

8. There are two other processes by which the length of AB can be ascertained by the use of the chain only without the cross-staff.

Select a convenient point C in front of the line AB (Fig. 48), from which both A and B are visible, and the lines CA, CB, chainable. These lines should be as nearly equal as possible. Measure BC and produce it to D, making DC equal to BC. Similarly measure AC and produce it to E making CE equal to AC. Then DE is equal and parallel to the obstructed line AB.

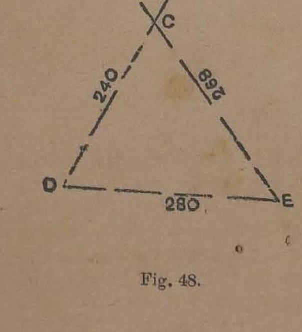


Fig. 48.

(4) A fourth method with the chain only—Construction of two similar triangles.

9. It often happens that space is not sufficient to admit of BC and AC being produced (Fig. 49). In such cases, measurement should be made as follows:—Select a point C as explained above. Measure BC. Divide it into two equal parts; and plant a peg E at the middle point. Measure AC and plant a peg also in the middle of the line at D. Measure DE and multiply the length obtained by two. The product is equal to the distance from A to B. The line DE is also parallel to AB.

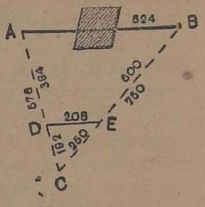


Fig. 49.

(b) Measuring an offset on a line obstructed as above.

(1) First method—Constructing a rectangle by producing both ways the base of a similar triangle formed in any triangle.

10. The manner of measuring offsets on an obstructed line, such as those of class II, differs from that described in paragraph 4 above only in the method by which we measure a line parallel and equal to the obstructed line. There are several ways of doing this, but one of the most accurate is that which has been just described in the previous paragraph. Having thus obtained ED parallel to and a half of AB (Fig. 50), the cross-staff is planted at a point F in the line of ED

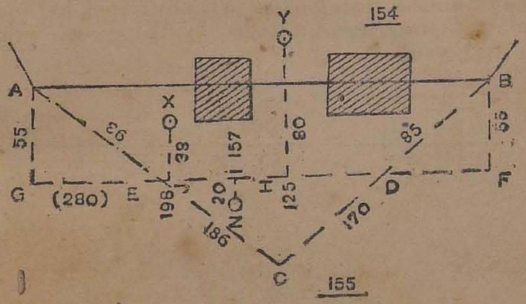


Fig. 50.

produced, so that when one groove is directed to E or D the other point to B: G is found in the same way. The line GF is now equal and parallel to AB. Offsets to any points may be measured from GF, and their positions in relation to the line AB discovered by subtracting from or adding to, 55 (the length of AG or BF), the distances to the objects measured from GF, according as they lie to the left or right of this line, starting from G.

(2) A second method—Converting a right-angled triangle into a rectangle.

11. The following method is usually practicable and is an easier and quicker method of laying down a line parallel to an obstructed line. In Fig. 51, AB is a line obstructed by a building. Set up the cross-staff at C within a chain's length of A, so as to sight both A and B and measure AC. At D, the same distance from B as C is from A, fix the cross-staff and again sight A and B. Then the line CD joining the points where the cross-staff stood is parallel to AB, and it can be made equal to it by producing both ends in exactly the same manner as that described above.

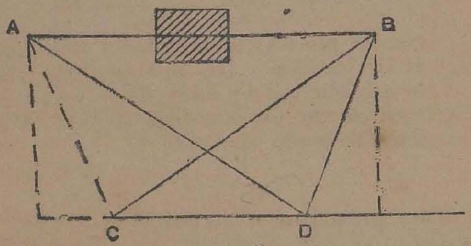


Fig. 51.

(3) A third method of measuring an offset on a line obstructed as above—Forming a similar triangle in a right-angled triangle and calculating the perpendicular.

12. Another method is also adopted for measuring an offset from a diagonal line obstructed by houses, etc. Suppose it is required to measure an offset to X from the line AB obstructed by houses (Fig. 52). Find the measurement of AB by the process explained in paragraph 6 (2) *supra*.

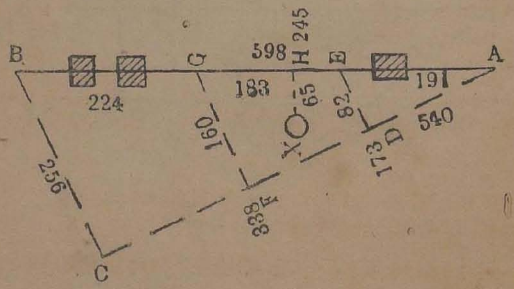


Fig. 52.

Let the right angle be at C. Measure BC and CA, the perpendicular and base of the right-angled triangle. The lengths are 256 and 540, respectively. AB is therefore 598. Proceeding along AC from A, suppose at D you find yourself clear of the obstruction. Fix your cross-staff at this point, view A and C through one groove, and through the other send a man in the direction of the obstructed line. We should now calculate the distance to be measured in this direction in order to

get into the obstructed line AB. This is obtained by multiplying the perpendicular of the right-angled triangle first formed with the chain distance now measured on the base and dividing the product by the length of the base.

The offset to be laid out at D is therefore $= \dfrac{BC \times AD}{AC}$

$$= \frac{256 \times 173}{540} = 82$$

Measure 82 links from D in the direction you sent the man and let him stand at E, which is in the line AB. The distance from A to E can also be calculated and is equal to $\sqrt{173^2 + 82^2} = 191$.

Proceed on the base AC and at another convenient point, say, F, fix, the cross-staff and repeat the process. The offset to be laid out from F to reach AB $= \dfrac{256 \times 338}{540} = 160$. Measure 160 links from F towards the obstructed line at right angles to AC, and thus you reach another point in the line AB. Call it G. The line between E and G is the line AB running through the houses. Measure EG and take on that line an offset to X. Let the length of the offset be 65 links. Suppose the offset to fall on EG at H, 54 links from E. The chain distance from A on the line AB will be AE + EH, *i.e.*, 191 + 54 = 245 links and the offset distance is 65 links.

(4) A fourth method of measuring an offset on a line obstructed as above—Converting a trapezoid into a rectangle.

13. Let it be required to take an offset to C from the obstructed line AB (Fig. 53). Construct a parallelogram ADFB in the manner explained in paragraph 7 *supra*, AB the obstructed line forming one of its sides. FD is parallel and equal to AB. Offset B on DF at the point G and A at H on the line HD produced. The figure BGHA is a rectangle. Offsets are then measured in the manner already explained.

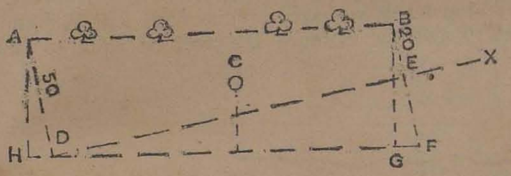


Fig. 53.

(c) Measurement where the offset itself is obstructed.

14. When measuring an offset on an obstructed line, it sometimes happens that either the stone to be offsetted is not visible from the line drawn parallel to the obstructed line or the offset from the stone where visible falls in an inconvenient point on the chain line. The offset to the stone and the chain distance should in such cases be measured as follows:—

See Fig. 54. Set up the cross-staff at a convenient point, say, M, on the line XY, view XY through one groove and direct a man through the other to a certain point say, P. On the line MP take an offset to C at N.

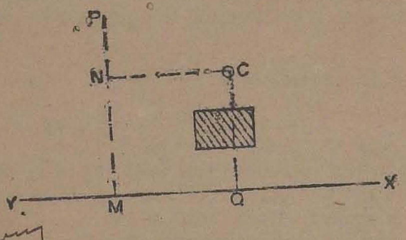


Fig. 54.

The chain distance on the line XY at which an offset to C falls is equal to XM — NC and the offset distance is equal to MN.

Where the stone to be offsetted is visible but not accessible being surrounded by thick prickly-pear, the chain distance can be determined by direct measurement on the line XY. For getting the length of the offset CQ proceed as above and measure NM.

Class III.—(*a*) One of the two stations alone accessible and the other visible but the distance between them not chainable.

(1) One method—Construction of two equal right-angled triangles.

15. We shall next consider how to overcome obstacles included in class III. A river in flood affords the best illustration of obstructions of this kind. Suppose the surveyor is at B in Fg. 55 and it is required to measure AB when A is visible from B but cannot be reached. Set up the cross-staff at B and viewing A through one groove direct a man through the other to stand at a distance approximately equal to AB, say at C. Fix a flag at C. Produce BC to D and make CD equal to BC. Take the-cross staff to D and sighting B or C send a man forward in the direction of the other groove to a convenient distance, say E. Leaving the cross staff at D, walk along DE produced having E and D in sight and stop when you are in a line both with AC and DE. Call this point F, and the distance DF will be equal to the distance AB.

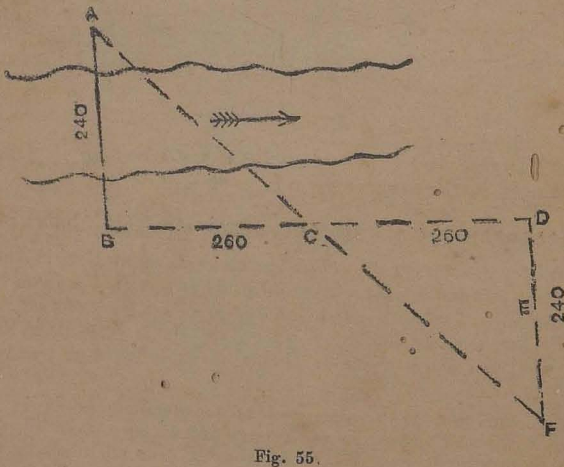


Fig. 55.

(2) Another method—Construction of similar right-angled triangles.

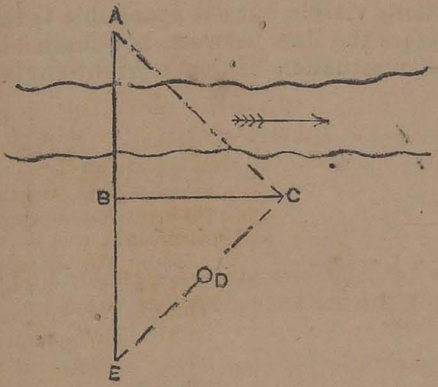


Fig. 56.

16. See Fig. 56. Set up the cross-staff at B and viewing A through one groove, direct a man through the other to stand at a distance approximately equal to AB, say at C. Next set up the cross-staff at C, view A through one groove and through the other direct a man to a convenient distance, say D. Leaving the cross-staff at C, walk along CD produced having D and C in view and stop when you are in a line both with CD and AB. Call this point E.

Now, $AB \times BE = BC^2$—see Chapter III.

$$\therefore AB = \frac{BC^2}{BE}.$$

(b) Measuring an offset on a line obstructed as above.

17. Suppose it is required to take an offset to a water-gauge X standing in the river on the line BA (Fig. 57). Let G be the point on which the offset from X falls on BA. We have to find the length of BG and GX, the chain and offset distances respectively. Find the length of BA as above. Offset X on the line BC from a point F, 30 links from B. BF is equal to GX, and FX is equal to BG. The length of FX is found by the same process explained above. Suppose XF measures 150. BG is also 150. On the line BA you thus get an offset of 30 links to the water-gauge X at a chain distance of 150 from B.

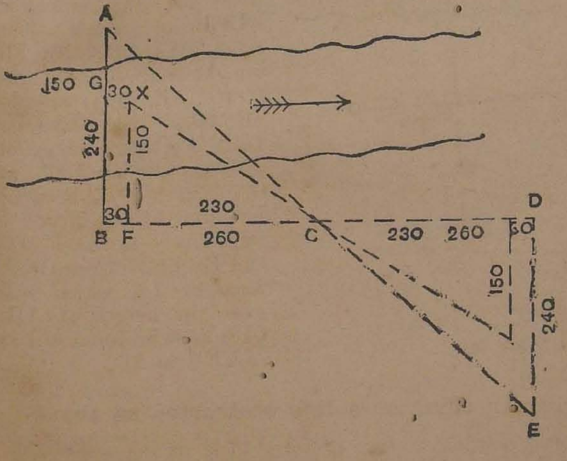


Fig. 57.

This process is also used for measuring obstructed offsets of the kind referred to in the latter part of paragraph 14 *supra*.

Class IV.—(*a*) Both stations visible but not accessible to the surveyor and therefore the line between not chainable from his position—Construction of equal right-angled triangles.

18. We now have to consider the last class of obstacles. A typical instance of this class of difficulty is when both stations are on the same side of a river, and the surveyor, on the opposite bank, wishes to measure the distance between them. Though he can see both stations he cannot reach them. For example in Fig. 58, the length of AB is required to be found from the other side of the river. Set up the cross-staff at C and sight A through one groove. Through the other send a man forward to any convenient point D, and proceeding along CD find with the cross-staff a point E from which B can be offsetted. The lengths of AC and BE are found by the process just explained and we thus get the trapezoid ACEB of which three sides, AC, CE, and EB are known, so that the fourth, AB, can easily be calculated. See Chapter III. A quicker and easier process is to bisect CE at G (Fig 59). Produce BE and AC to H and I respectively to meet AG and BG likewise produced. Measure IH which will give the length of AB. CI is likewise equal to BE and EH to AC.

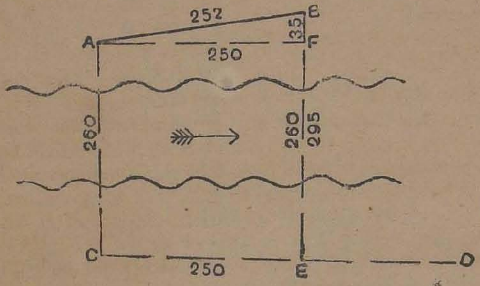


Fig. 58.

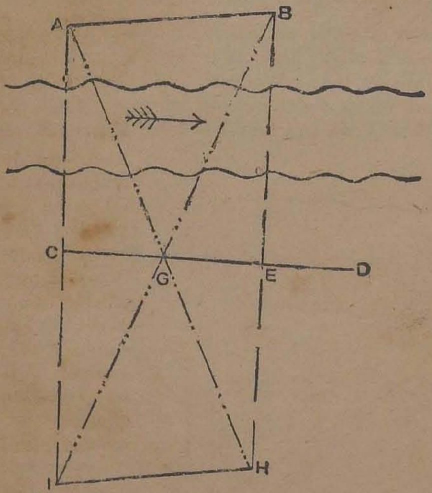


Fig. 59.

(*b*) Measuring an offset on a line obstructed as above

19. Suppose it is required to take an offset to M on the inaccessible diagonal line AB (Fig. 60). First find AB in the manner just described in paragraphs 16 to 18. Thus the length of AC and BD will

be obtained. Produce AC to E making AE equal to BD. Join ED and produce it to G at which point BG makes a right angle with EG, to be ascertained with the help of the cross-staff at G. A is also offsetted at the point F. Then FG is both equal and parallel to AB.

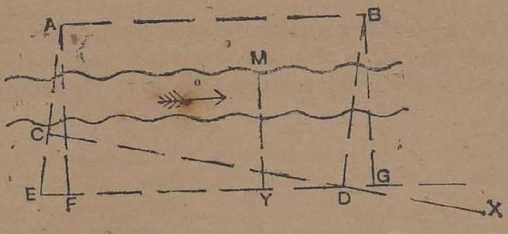


Fig. 60.

AE and EF are known; so AF can be calculated, because AFE is a right angle; and now the distance of any point M from the line AB can be discovered by first finding the length of MY, which must be at right angles to FG, and subtracting it from AF. The chain distance of M from A along AB is of course equal to FY.

Class V.—Measurement of obstructed lines in special cases.

(*a*) Betel gardens, village sites and similar fields.

20. When fields are impenetrable owing to thick growth of vegetation such as betel or prickly-pear or to houses, it may not be possible to measure them under the triangulation and offset system described in Chapter VI. In such cases, the fields should be measured by offsetting all stones on the sides of a large well-conditioned triangle or a rectangle or a trapezoid conveniently formed round the field.

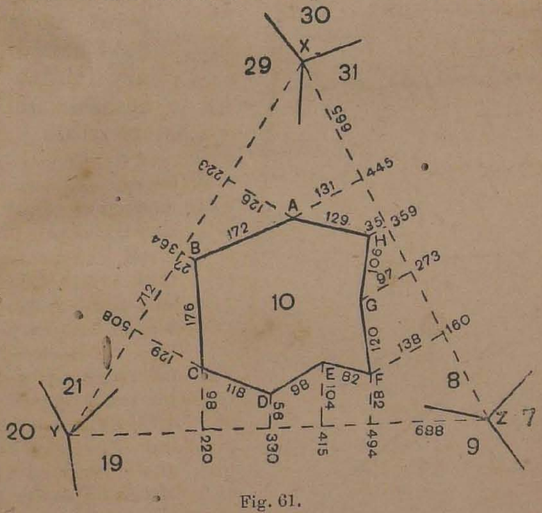


Fig. 61.

(*See* Figs. 61 and 62.) Diagonals measured between trijunction stones in the adjoining fields should, as far as practicable, be selected for the sides of the figure thus formed. Where this is not possible, the points selected should be field bends and they should each be connected by not less than three tie lines with the nearest field trijunctions. The

lengths of the 'Fs' of the obstructed field may be calculated from the offset and chain measurements as explained in Chapter III.

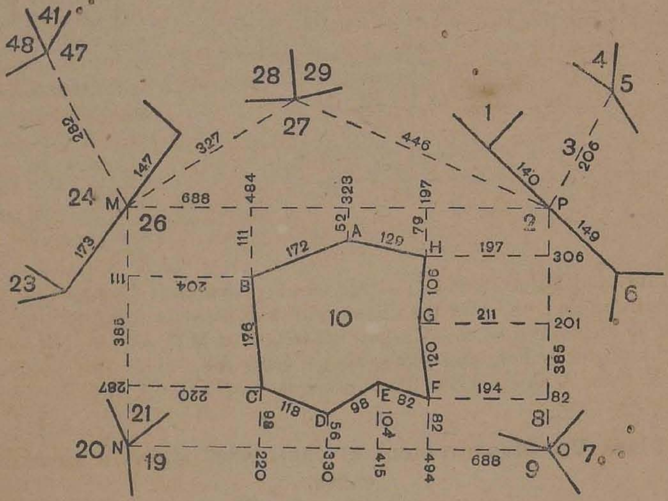


Fig 62.

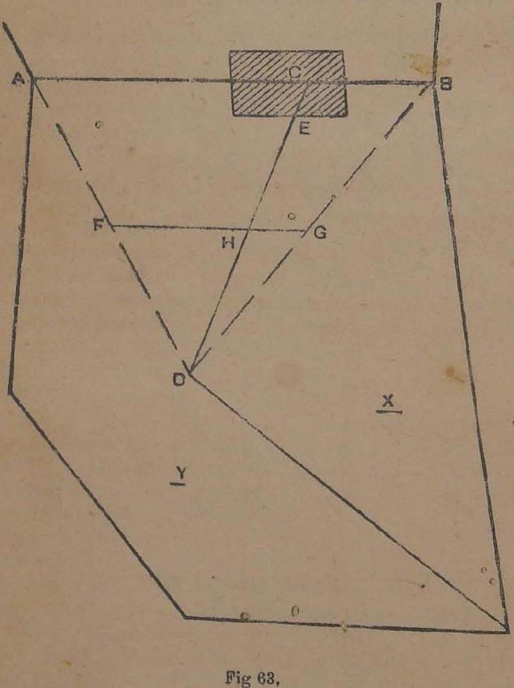


Fig 63.

(*b*) **Where a sub-division point in a field boundary is inaccessible and invisible.**

21. In the course of measurement of sub-divisions, it often happens that a sub-division point in the field boundary line i[s] inaccessible and invisible rendering it difficult to ascertain the length of the segments of the latter and also the length of the sub-division boundary. In Fig. 63, X and Y are two sub-divisions in a

field. The sub-division boundary DC can be traced on the ground as far as E. The continuation of DE falls in an inaccessible tank in which the point C cannot of course be traced. It is required to ascertain the lengths of AC, BC and DC

Measure DA and bisect it at F. Measure DB and bisect it at G. Measure FG. Let H be the point, where it meets DE. Measure FH, GH and DH.

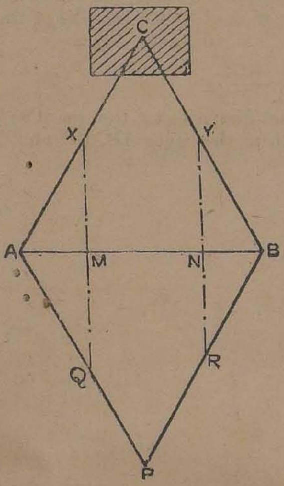


Fig. 64.

AC = 2×FH ; BC = 2×HG; DC = 2×DH. Again suppose the sub-division lines AC and BC (Fig. No. 64) meet at an inaccessible and invisible point C and the direction of the lines is indicated by a bund or ridge running through points X and Y respectively. The measurement of AC and BC can be found as follows :—Join AB. On it offset X and Y at M and N. Produce XM to Q making MQ equal to XM. Similarly produce YN to R making NR equal to YN. Next produce AQ and BR to meet at P. Then AP = AC and BP = BC.

(c) Calculation of chain and offset distances on an obstructed line from those measured on another line.

22. In paragraphs 4, 10, 11, 12 and 13 *supra*, various methods have been explained for measuring offsets on obstructed lines. It is sometimes found impossible to fix points in an obstructed line or to form a line parallel thereto. In such cases, the ends of the obstructed line and

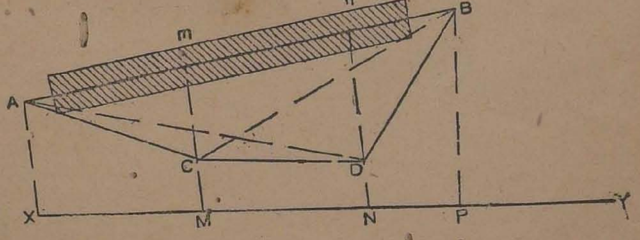


Fig. 65.

also the points which it is required to offset in that line may be offsetted on any convenient line and the chain and offset distances calculated as follows :—

Fig. 65, it is required to offset C and D on AB. Offsets were taken to A, C, D and B on any line XY at points X, M, N and P respectively. The length of the sides AC, CD, DB and AB can be calculated with reference to the formula explained in Chapter III. Likewise the length of AD and BC. The method of calculating chain and offset distances in a triangle when 3 sides are given is explained in Chapter IX. By means of the formula therein given the chain distance at which an offset from C falls on the line AB can be determined by the lengths of the sides AC, CB and AB of the triangle ACB. Chain distance AE =

$$\frac{AB^2 + AC^2 - BC^2}{2 \times AB}.$$

Offset $EC = \sqrt{AC^2 - AE^2}$.

In the same way, the chain and offset distances to the point D on the line AB can be found out by the length of the sides AB, BD and DA of the triangle ADB.

Chapter VIII.—Plotting.

Plotting is the process of preparing a map or plan of a piece of land, showing the correct shape on paper, according to the distances that have been measured on the ground.

Instruments required for plotting a chain survey.

2. A *scale*, *an offset scale* and a pair of *compasses* are essential for plotting a chain survey.

Scale and offset scale.

3. The plotting scale is a flat piece of wood with a straight edge on which are marked divisions representing chains and tenths of a chain or ten links. The scale of a map shows the ratio of the length of any line on the map to the length of the line it represents on the ground. If one chain is measured on the ground and if an inch is allotted on the map to represent it, the map is said to be drawn to the scale of one inch equal to one chain or 80 inches equal to one mile, there being 80 chains in a mile (Fig. 66). Similarly a map drawn to the scale of *one inch equal to two chains* or 40 inches equal to one mile means that a distance of two chains on the ground is represented on the map by one inch or that of one mile by 40 inches

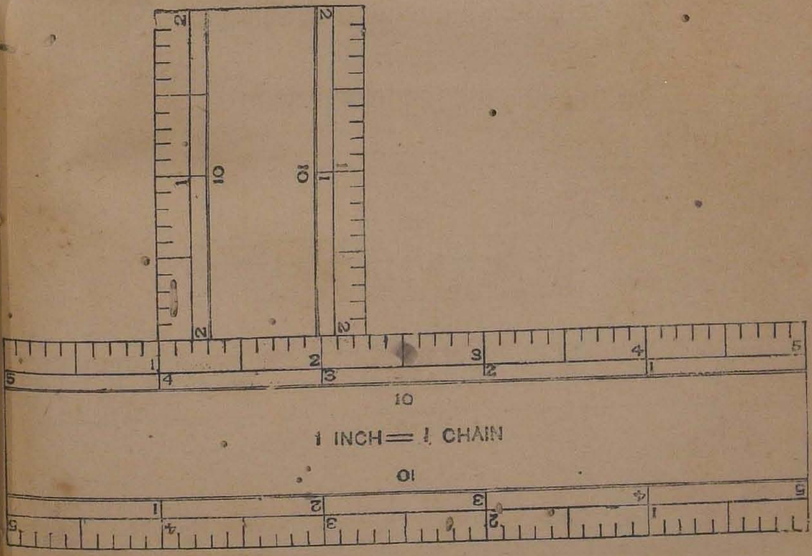


Fig 66.

(Fig. 67). In a scale of one inch equal to five chains or 16 inches equal to one mile, a distance of five chains and of one mile on the ground are respectively shown in the map by one inch and 16 inches. (Fig. 68.) On the same piece of wood, it is convenient to draw two different scales one on each bevelled edge—*vide* Fig. 68. The three scales explained above are the most useful for drawing field maps.

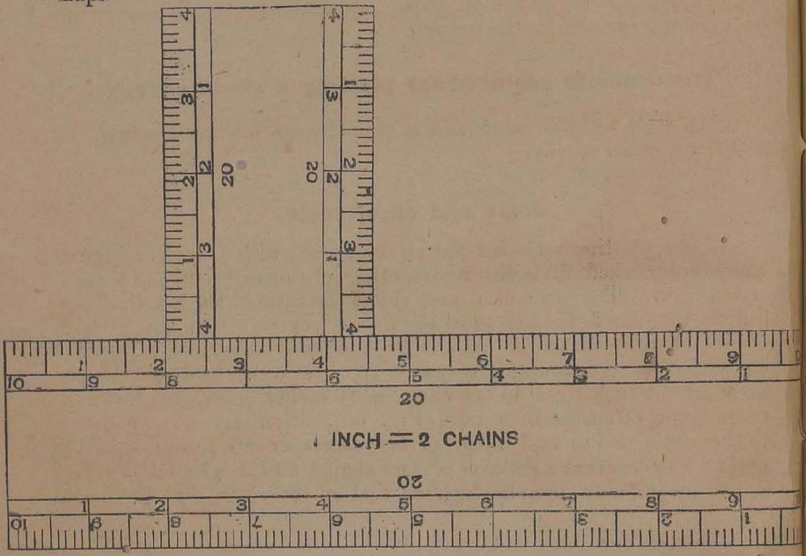


Fig. 67

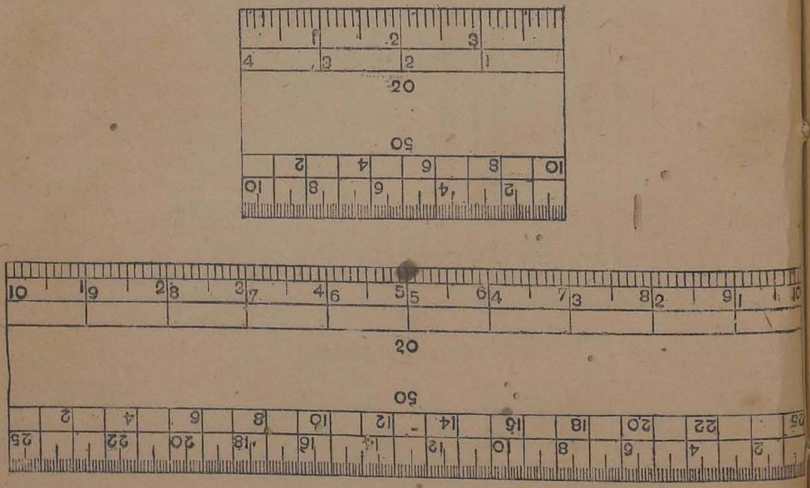


Fig. 68.

4. For convenience in plotting offsets, a short piece, called the *offset* bit (see Fig. 68) marked with the same divisions, is used with the plotting scale. It is made to slide along the edge of the plotting scale for the purpose of laying down on the paper, at right angles to the line representing the chain-line, the offset distances measured in the field. The scale and offset bit thus correspond to the chain and offset pole. It will be seen therefore that in plotting a field measured with the chain only under the simple triangulation system, no offset bit is necessary.

Compasses or dividers.

5. The compasses or dividers (Fig. 69) consist of two legs movable about a joint so that their extremities may be set at any distance from one another. The upper portion and the joint are usually made of brass, the legs of steel ending in fine points. They should be held at the top between the fore-finger and the thumb, with one or more fingers under the hinge to increase or diminish the distance between the point gradually and without a jerk. In plotting triangles, draw the base first with the scale. Adjust the compasses on the scale to agree with the length of one of the sides, and with one point on the corresponding end of the base, scratch *lightly* on the paper a portion of a circle with the other point of the compasses where you estimate the apex of the triangle will be. Now take off the scale the length of the remaining side, and similarly scratch a portion of another circle, taking as its centre the other end of the base. The apex of the

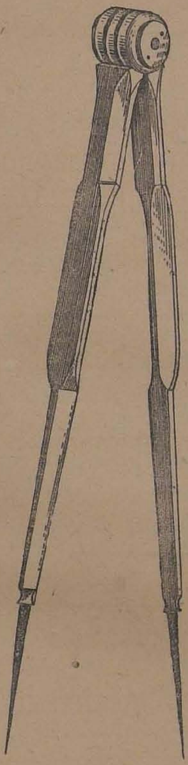


Fig. 69.

triangle lies where the two circles intersect, and the sides can then be drawn in or not as required. A little consideration will show that very small portions only of the circles need be described and care should be exercised that the scratches on the paper are merely deep enough to be visible, so that the appearance of the plan is not spoilt by them (Figs. 70 and 71).

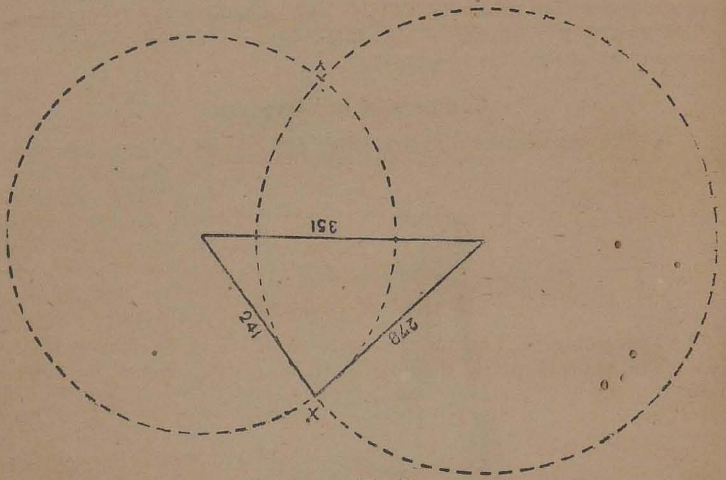


Fig. 70.

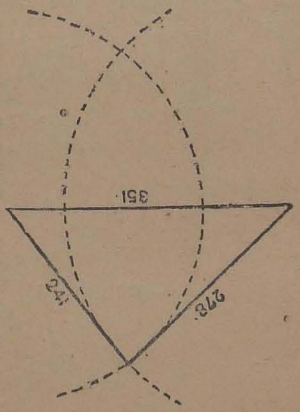


Fig. 71.

Additional plotting instruments.

6. A drawing pen (Fig. 72) and a flat ruler (Fig. 73) for inking in pencil lines, are additional aids to neat plotting though they are not indispensable.

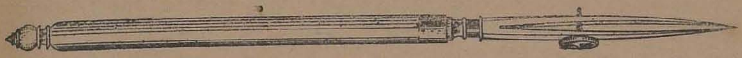


Fig. 72.

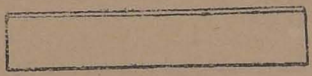


Fig. 73.

Method of plotting.

7. The pointer indicating the north should first be drawn (Fig. 74). The scale to which the map is to be plotted should next be decided and

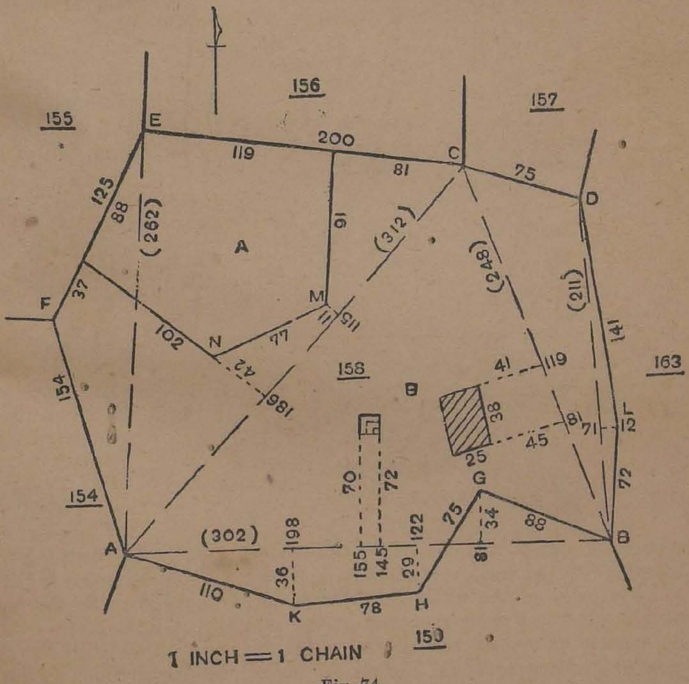
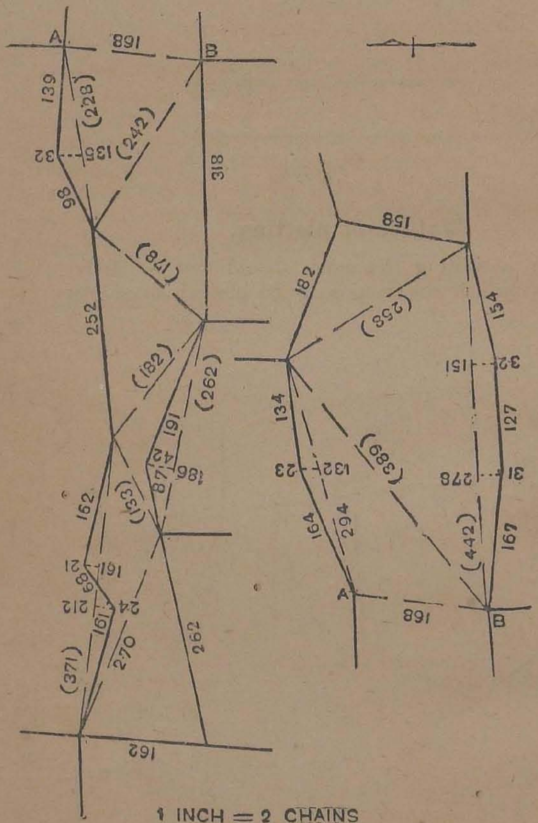


Fig. 74.

noted on the paper. The smaller the field in extent, the larger should be the scale. Fields of less than five and ten acres in extent are generally plotted to scales of one inch equal to one chain and two chains respectively. Fields of over ten acres are plotted to the scale of one inch equal to five chains. Long narrow tracts, such as channels and roads, are plotted in sections as shown in diagram No. 75. The sides of the triangles should be first plotted, then offsets and lastly the outer boundaries of the field. For example in diagram No. 74, draw the diagonal AB and on it construct the triangle ACB. Then plot the triangles AEC, AFE and CDB, and now the offsets from the diagonals to the bends situated on their sides. On the line AB the offsets are to G, H and K; draw the lines BG, GH, HK, and KA, verifying the recorded distances with those obtained with the scale. Similarly plot the offset to L from BD; join BL and LD, and verify their lengths with the scale. The field has now been completed. Next proceed to plot the subdivisions. Mark the sub-division points on the 'F' lines EC and EF, plot the offsets to the corners M and N, and draw the sub-division 'F' lines, verifying their lengths with the scale. If in thus verifying the sub-division 'F' lines and also those of the whole field, the measurements gvien by the scales do not tally with those recorded in the rough sketch the latter should be checked again on the ground. Having now drawn all the line enter the measurements bearing in mind the instructions given in paragraph 9 of Chapter VI *supra.*



1 INCH = 2 CHAINS

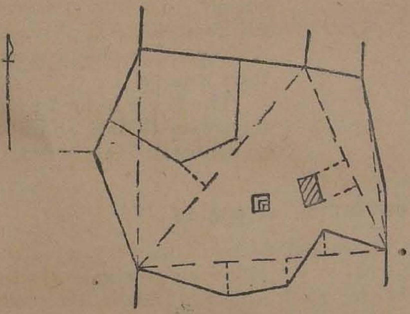
Fig. 75.

8. The lines should first be drawn in pencil and then inked with the drawing pen after being tested with the scale. A field boundary line should be continuous and thick. The " G " and offset lines should be lightly drawn and dotted. A sub-division boundary line should be continuous like the field boundary line, but should not be drawn so thick. Trijunctions of fields should be indicated by short lines drawn at the points where the three boundaries meet. The numbers of adjoining fields should be noted in appropriate places. These are called side numbers. Details, if any, should be plotted last of all.

Enlargement and reduction.

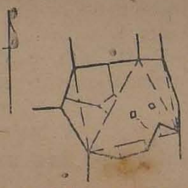
9. The scale of plan should be governed by the purpose for which it is to be used. In the 16″ or 8″ village map, we see plans of the fields drawn on a scale small enough to allow the whole village, or a large part of it, to be shown on one piece of paper, so that we may see at a glance the positions of the fields in relation to one another. The Field Measurement Book, on the other hand, is prepared on a much larger scale with the object of showing distinctly the measurements, sub-divisions, and other details which it would be impossible to plot clearly on the village map.

10. If a plan be drawn to a scale of 1 inch = 2 chains and it is required to enlarge it to the scale of 1 inch = 1 chain, it is easy to understand that a line 1 inch long in the first will be represented by a line 2 inches long in the second. The effect, however, upon the area of the plan is not that of *doubling* it, but of *squaring* it. Thus a square whose sides are 1 inch would be drawn with sides of 2 inches: but the area of the 1st would be 1 sq. inch; where as in the 2nd it would be 4 sq. inches. If it were enlarged from 1 inch = 5 chains to 1 inch = 1 chain, the second square would require sides 5 inches long and its area would be 25 sq. inches. So we gather that if a plan be enlarged, its area varies as the



INCH = 2 CHAINS

Fig 76.



1 INCH = 5 CHAINS

Fig. 77.

squares of the scales. Similarly if it be reduced, its area diminishes in the same proportion. The area of the plan must not be confused with the area of the ground. The latter of course always remains the same, but it can be represented on paper by pictures of any size (Figs. 76 and 77).

11. Enlargements or reductions can be made when no measurements are recorded on a plan by scaling off the lengths of the lines and multiplying or dividing by the number of times it is required to enlarge or reduce them. The following method is also generally adopted—see Fig. 78. Let ABCDEF be the figure which is required to be reduced to, say, half its scale. From any point as A draw lines to all the angular points of the figure. In AF, AE, AD, AC and AB, mark off points M, L, K, H, and G, such that AM, AL, AK, AH, and AG, may be exactly half of AF, AE, AD, AC, and AB, respectively and join M, L, K, H and G. Then AGHKLM will be on half the scale of ABCDEF.

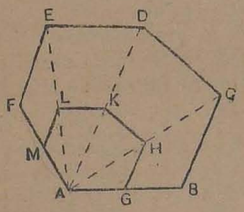


Fig. 78.

If AGHKLM be the given figure and it is required to enlarge it to double its scale then the lines AG, AH, AK, AL, and AM should be produced to double their lengths.

The figure formed by joining the points BCDE and F will be on double the scale of AGHKLM.

Conversion of scales.

12. Given a scale and the measurements of a survey, a plotting may be prepared to any other scale by the following process:—Multiply the recorded measurements by the given scale and divide the product by the scale to which it is required to plot the survey. Plot the resultant measurements to the given scale and the map drawn will be to the scale required. For example, a scale of 1 inch = 2 chains and the measurements of a survey are given. To get a plotting to a scale of 1 inch = 5 chains, multiply each of the measurements by two and divide the product by five. Plot the resultant measurements to a scale of 1 inch = 2 chains and the map drawn will be to a scale of 1 inch = 5 chains. The recorded and not the deduced measurements should be entered in the plotting.

How village, taluk and district maps are prepared.

13. A very good example of the reduction of plans is seen in the maps of the taluk and district. The field maps are joined together on a small scale to form the village map; taluk maps consist of a collection of the village maps on a still smaller scale, and the district map is again further reduced from the taluk maps.

Chapter IX.—The Computation of Area.

After a field has been plotted, its area should be computed. This may be done either by using the *area square paper* or by *mathematical calculation.*

Construction and use of the area square.

2. *The area square* is a piece of tracing cloth or tissue paper on which are neatly drawn or printed to the scale required, black ink squares each containing 10 cents, *i.e.*, one-tenth of an acre. The black ink squares are again divided by red ink lines into 10 equal portions, each equivalent to one cent or one one-hundredth part of an acre (Fig. 79).

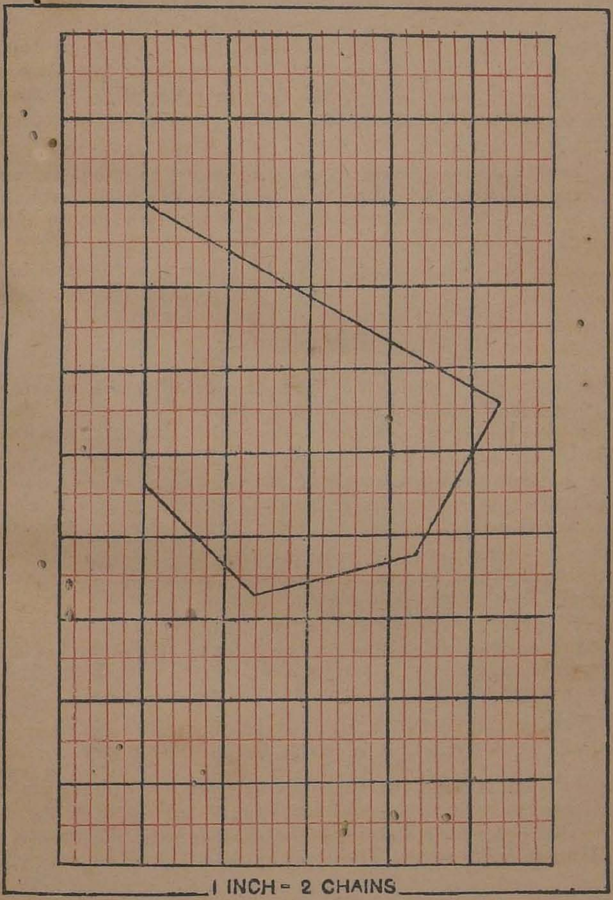


Fig. 79.

Lay the area square paper over the plotting of the field, the area of which is sought, so that the boundary of the field is clearly visible and the extreme east or west of it at the corner of one of the ten cent squares, while one of the sides of the field coincides exactly with a black line on the area square paper. The area is then found by counting the number of black and red squares contained within the boundary of the field. If the boundary line does not exactly coincide with a horizontal line of the area square nor is parallel to it, equalize any irregularities by the eye so that the space within the field and that outside it may be equal to and compensate each other.

Procedure to be followed when scales of area square and plan differ.

3. It sometimes happens that the scale of the area square is different from the scale of the plan of the field, the area of which is required to be computed. In such cases, the correct area is obtained by multiplying the area actually obtained, by the square of the scale on the plan and dividing the product by the square of the scale on the area square paper; care being taken that the scales of the plotting and the area paper are first reduced to a common denomination expressed in terms of chains per inch.

For example.—On a plotting of one inch equal to 2 chains, an area square paper drawn to 16 inches equal to 1 mile, is applied, and an area 50 acres obtained. First express the scale of the area square paper in terms of chains to an inch that is 1 inch equals five chains. Now apply the formula. The correct area is $\frac{50 \times 4}{25} = 8$ acres.

Exercises.

1. On a plotting of one inch equal to one chain, an area square paper drawn to a scale of one inch equal to 3 chains was applied. The area computed was 120 acres. What was the correct extent? Ans. 13 acres 33 cents.

2. A field was plotted to a scale of 80 inches equal to one mile and its area computed with an area square drawn to the scale of one inch equal to 2 chains was 65 acres 20 cents. Find the correct extent. Ans. 16 acres 30 cents.

3. The application of area square of one inch equal to 3 chains on a plotting of 16 inches to a mile gives an area of 96 acres. Find the true area. Ans. 266 acres 67 cents.

4. The area of a field plotted to 160 inches a mile computed with an area square of ten inches to a furlong is 49 acres. What is the true area? Ans. 12 acres 25 cents.

Calculation of area mathematically.

4. With the area square, areas can be computed quickly and easily and with sufficient accuracy for revenue purposes generally. If the exact number of square links is to be determined, calculations must be made mathematically. The most important formulæ are explained below:—

Area of a rectangle.

5. The area of a *rectangle* is obtained by multiplying the length by the breadth— Fig. 80.

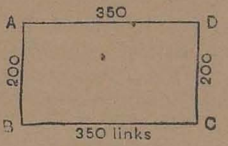


Fig. 80.

The area of the rectangle **ABCD** = **AB** × **BC** = 200 × 350 = 70,000 square links or 70 cents.

Area of a triangle.

6. The area of a *triangle* is obtained by multiplying together the base and the offset falling on it from the opposite angle, and dividing the product by two— Fig. 81. Thus the area of the triangle **ABC** = $\frac{AB \times CD}{2} = \frac{550 \times 320}{2}$ = 88,000 square links or 88 cents.

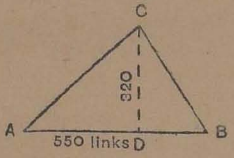


Fig. 81.

Sometimes the offset falls outside the triangle as shown in Fig. 82. The same formula holds good in this case also. The base of the original triangle multiplied by the offset and divided by two gives the area required. The area of the triangle **ABC** = $\frac{AB \times CD}{2} = \frac{550 \times 320}{2}$ = 88,000 square links or 8 cents.

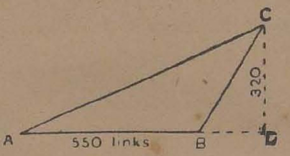


Fig. 82.

Area of a quadrilateral with a diagonal and offsets on either side.

7. The area of a *quadrilateral* divided into two triangles by a diagonal with an offset taken on it for each triangle is obtained by multiplying the length of the diagonal with the sum of the offsets and dividing the product by two. (Fig. 83.) The area of ABCD = $\frac{AC \times (EB + FD)}{2} = \frac{500 \times (160 + 240)}{2}$ = 100,000 square links or 1 acre.

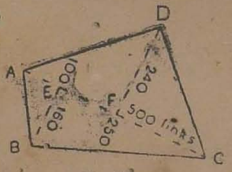


Fig. 83.

Area of a trapezoid.

8. The area of a *trapezoid* is obtained by multiplying the sum of the two offsets with the perpendicular distance between them and dividing the product by two. (Fig. 84.)

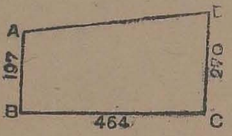


Fig. 84.

The area of the trapezoid $ABCD = \frac{(AB + DC) \times BC}{2} = \frac{(197 + 270) \times 464}{2} = 108{,}344$ square links $= 1{\cdot}08$ cents.

9. To find the area of an irregular field such as that sketched in Fig. 85. Imagine it to be made up of a number of separate figures, find the area of each separately and add them together. First, for convenience, number the figures.

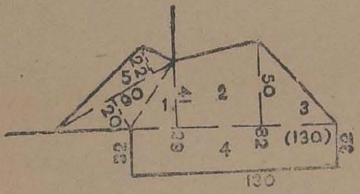


Fig. 85.

No. 1 is a right-angled triangle and its area is	$\frac{29 \times 41}{2}$	$= 594\frac{1}{2}$ sq. links.
„ 2 is a trapezoid „	$\frac{(82-29) \times (50+41)}{2}$	$= 2{,}411\frac{1}{2}$ sq. links
„ 3 is a right-angled triangle „	$\frac{(130-82) \times 50}{2}$	$= 1{,}200$ „
„ 4 is a rectangle „	130×32	$= 4{,}160$ „
„ 5 is a quadrilateral „	$\frac{90 \times (22+20)}{2}$	$= 1{,}890$ „
	Total area of field	$= 10{,}256$ „

Calculation of the chain and offset distances in a triangle.

10. Sometimes we find no offset measured in a triangle the area of which is required to be calculated mathematically. The chain and offset distances can be calculated from the measurements of the sides as follows:—

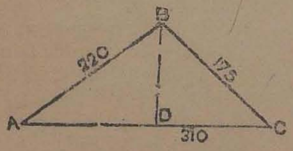


Fig. 86.

Suppose it is required to find the lengths of AD and BD, the chain and offset distances in the triangle ABC. (Fig. 86.)

The length of AD is obtained by adding the square of AB, its adjacent side, to the square of AC, the base of the triangle, subtracting from the result the square of BC, the side opposite to AD, and dividing the remainder by twice the length of AC, the base.

AD is therefore =

$$\frac{AC^2+AB^2-BC^2}{2\,AC}=\frac{310^2+220^2-175^2}{2\times310}=\frac{96,100+48,400-30,625}{620}=184.$$

The formula is arrived at as follows:—

$BD^2 = AB^2 - AD^2$

BD^2 is also $= BC^2 - DC^2$

$\therefore BC^2 - DC^2 = AB^2 - AD^2$

By transposition, $AD^2 - DC^2 = AB^2 - BC^2$

But $AD^2 - DC^2 = (AD + CD) \times (AD - DC)$

$\therefore (AD + CD) \times (AD - DC) = AB^2 - BC^2$

(1) $\therefore AD - DC = \frac{AB^2 - BC^2}{AD + CD}$

(2) But $AD + DC = AC$

Add (1) and (2) $\therefore 2AD = \frac{AB^2-BC^2}{AD+DC} + AC = \frac{AB^2-BC^2}{AC} + AC$

$$= \frac{AB^2 - BC^2 + AC^2}{AC}$$

$$AD = \frac{AB^2-BC^2+AC^2}{2AC} = \frac{AC^2+AB^2-BC^2}{2AC}$$

$$= \frac{310^2 + 220^2 - 175^2}{2 \times 310} = 184.$$

An alternative and simpler proof is as follows:—

By Euclid II, 13, $BC^2 = AB^2 + AC^2 - 2AC.\,AD$

Divide both sides by 2AC and we get $\frac{BC^2}{2AC} = \frac{AB^2+AC^2}{2AC} - AD$

That is $AD = \frac{AB^2 + AC^2 - BC^2}{2AC}$

Similarly the chain distance CD

$$= \frac{AC^2 + BC^2 - AB^2}{2AC}$$

$$= \frac{310^2 + 175^2 - 220^2}{2 \times 310} = \frac{96,100 + 30,625 - 48,400}{620}$$

$= 126.$

When AD is known, BD can be found by the formula already explained in chapter III.

$BD^2 = AB^2 - AD^2$.

$BD = \sqrt{220^2 - 184^2} = 121.$

The area of the triangle ABC

$$= \frac{310 \times 121}{2} = 18,755 \text{ square links.}$$

Calculation of area of a triangle without finding out the offset.

11. Without calculating the offset, in the manner explained above, the area of a triangle may be found as follows:—First subtract each side separately from half the sum of the three sides; multiply the half sum and three remainders together; the square root of the product will be the area in square links. Suppose the sides of a triangle to be 12, 14 and 18 links.

Half the sum of the sides $= \frac{14 + 18 + 12}{2} = 22$

Subtract 12, 14 and 18 separately from 22

The remainders are 10, 8, 4.

Multiply 22 and 10, 8, 4 together

$22 \times 10 \times 8 \times 4 = 7040$

The square root of 7040 is 84.

The area of the triangle in question is 84 square links.

Calculation of area when offsets fall within or without the field boundary on the same diagonal.

12. In some cases it happens that some of the offsets taken on a diagonal line to the bends fall within, and others without, the figure formed by the diagonal and the other sides of the field—*vide* diagram No 87. In such cases the field boundary line crosses the diagonal. The point of intersection of these two lines should be noted if it is required to calculate the area of the field mathematically. If this is not done in the field, the distance can be calculated as follows :—

In Fig. 87, the offset EB falls outside the triangle AGD and the offset CF within it. X is the point of intersection of EF and CB. The chain distances on the diagonal AD to offset points B and C have been noted. The area of the triangles AEB and CFD can be found as they contain the necessary measurements. The area of one has to be added to, and that of the other subtracted from the big triangle AGD in order to obtain the area of the field. The difficulty is only in regard to the small triangles FCX and XEB. To calculate the area of these two triangles the distance from E to X and X to F should be known.

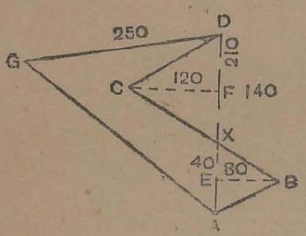


Fig. 87.

EX is the base and EB the perpendicular in the right-angled triangle XEB. The length of the base EX is obtained by multiplying the distance between the two offsets EB and CF with the length of its own perpendicular (*i.e.*, EB) and dividing the product by the sum of the two offsets. The distance between the two offsets is 140—40=100.

$$\text{Therefore EX}=\frac{\text{EF}\times\text{EB}}{\text{CF}+\text{EB}}=\frac{100\times 80}{120+80}=\frac{8{,}000}{200}=40.$$

$$\text{Similarly XF}=\frac{\text{EF}\times\text{CF}}{\text{CF}+\text{EB}}=\frac{100\times 120}{120+80}=\frac{12{,}000}{200}=60.$$

The sides EX and XF being thus known, the area of the triangles CFX and XEB can be calculated. The area of CFX = $\frac{60\times 120}{2}$ = 3,600. The area of XEB = $\frac{40\times 80}{2}$ = 1,600. The area of the former has to be subtracted from, and that of the latter added to, the big triangle ADG. The net result is a subtraction of 2,000 square links from the triangle ADG.

13. The length of the " F " line CB can also be determined by finding out the distances of CX and XB, the hypotenuses in the right-angled triangles CFX and XBE, respectively.

BX is accordingly $= \sqrt{80^2 + 40^2} = 90$

$CX = \sqrt{120^2 + 60^2} = 134$

$\therefore CB = 90 + 134 = 224.$

CB may also be found by another method.

The square of the boundary line = the square of the distance between the two offsets + the square of the sum of the offsets. See Chapter III.

$$i.e.,\ CB^2 = EF^2 + (CF + EB)^2$$
$$\text{Therefore } CB = \sqrt{EF^2 + (CF + EB)^2}$$
$$= \sqrt{100^2 + (120 + 80)^2} = \sqrt{10{,}000 + 40{,}000}$$
$$= \sqrt{50{,}000} = 224.$$

14. Without calculating the length of EX and XF, the difference in area between the two triangles FCX and XEB can be ascertained by the following formula. Multiply the distance between the two offsets with the difference of the lengths of the two offsets and divide the product by two.

The difference in area between FCX and XEB,

$$= \frac{100 \times (120 - 80)}{2} = \frac{100 \times 40}{2} = 2{,}000 \text{ square links.}$$

This difference has to be added to or subtracted from the big triangle according as the length of the offset falling outside the triangle is longer or shorter than the offset falling within it.

In the present case the offset EB falling outside the triangle being shorter than FC, the difference in area 2,000 square links should be subtracted from the area of the big triangle ADG.

Correction of areas of plottings prepared from measurements taken with an incorrect chain.

15. It sometimes happens that not until a field has been plotted and its area computed is it found that it was measured with a chain which was either too long or too short. In such cases, the whole work need not be redone. The correct area is obtained by multiplying the incorrect area by the square of the length of the incorrect chain and dividing the product by the square of the length of the correct chain :

$$\text{Correct area} = \frac{\left(\begin{array}{c}\text{length of the}\\ \text{incorrect chain}\end{array}\right)^2 \times \begin{array}{c}\text{Incorrect}\\ \text{area}\end{array}}{(\text{Length of the correct chain})^2}.$$

Example.—The area of a plotted field has been computed and found to be 50 acres. It was subsequently found to have been measured with a chain which was 3 links too long. Required the correct area.

$$\text{The correct area} = \frac{(103)^2 \times 50}{(100)^2} = 53 \text{ acres, } 4\tfrac{1}{2} \text{ cents.}$$

Exercises.

1. A plotted field with an area of 56 acres was subsequently found to have been measured with Gunter's chain 5 links too short. Find the correct area. Ans. 50·54 acres.

2. A field was measured with a Gunter's chain which was 4 links too short. It was plotted and its area found to be 69 acres 15 cents. Find the correct area without remeasurement. Ans. 63·73 acres.

3. A field was measured with a chain $3\frac{1}{2}$ links too long and was plotted and its area found to be 43 acres and 65 cents. Find the correct area of the field. Ans. 46·75 acres.

Exercises in calculation of area.

1. Find the area in square links of a rectangle, the length and breadth of which are 289 and 225 links, respectively. Ans. ·65025 square links.

2. Find the area in acres and cents of squares having the following lengths of sides :—

(*a*) 850 links, (*b*) 98 chains 8 links, (*c*) 20 chains 42 links, (*d*) 52 chains 4 links. Ans. (*a*) 7·22½ acres, (*b*) 961·97 acres, (*c*) 41·70 acres, (*d*) 270·82 acres.

3. Find the areas of the triangles having the following dimensions :—

(*a*) Base 456 links, offset 240 links. Ans. 54,720 square links.
(*b*) Base 246 links, offset 118 links. Ans. 14,514 square links.
(*c*) Base 819 links, offset 124 links. Ans. 50,778 square links.

4. Find the base of a triangle, the area of which is 97 cents and offset 125 links. Ans. 1,552 links.

5. Find the offset of a triangle, the area of which is 85 cents and base 189 links. Ans. 899 links.

6. Find the areas of the right-angled triangles having the following dimensions :—

(*a*) Hypotenuse 624, side 329. Ans. 87,185 square links.
(*b*) Hypotenuse 428, side 354. Ans. 42,657 square links.
(*c*) Two sides 515, 594, respectively. Ans. 152,955 square links.

7. Find the areas of quadrilaterals having the following dimensions :—

(*a*) Diagonal 538. Perpendiculars 90 and 70 links. Ans. 43,040 square links.

(*b*) Diagonal 629. Perpendiculars 124 and 131 links. Ans. 80,197 square links.

8. The two parallel lines in a trapezoid are 104 and 82 links, respectively and the perpendicular distance between them is 284. Find the area of the trapezoid. Ans. 26,412 square links.

9. The sum of the parallel sides in a trapezoid is 640 links and the perpendicular distance is 320. Find the area. Ans. 102,400 square links.

10. The area of a trapezoid is 3 acres. The sum of the two parallel sides is 384 links. Find the perpendicular distance between the two parallel lines. Ans. 1,563 links.

11. The area of a trapezoid is 87 cents; the perpendicular distance between the two parallel lines and the length of one of the parallel lines are 249 and 124, respectively. Find the other two sides. Ans. 575 and 515.

12. The perpendicular distance between the two parallel lines in a trapezoid is 748 links. One of the parallel lines is 425 and the side opposite the right angles is 853. Find the area of the trapezoid. Ans. 471,240 square links.

13. The two offsets in a trapezoid are 284 and 192, respectively. The side opposite the right angles is 392. Find the area of the trapezoid. Ans. 90,678 square links.

14. Find the area of the triangles having the following sides by finding out the offset :—

(*a*) 18, 25, 36. Ans. 198 square links.
(*b*) 538, 877, 929. Ans. 230, 856 square links or 2·31 acres.
(*c*) 254, 369, 425. Ans. 46,537 square links or 47 cents.

15. Find the area of the triangles having the following sides without finding out the offsets :—

(*a*) 529, 326, 298. Ans. 44 cents.
(*b*) 698, 349, 520. Ans. 88 cents.
(*c*) 297, 184, 315. Ans. 27 cents.

16. AFE is a triangle—the side AF is 532, FE 356 and AE 449. On the line AE, the following offsets were recorded from bends B, C and D :—

	E	
	398	75 D.
C 121	295	
	224	86 B.
	A	

Find the area of the figure ABCDEF and the measurements of AB, BC, CD and DE. Answer AB = 240 ; BC = 219 ; CD = 221 ; DE = 91 ; Area = 87 cents or 71 cents according as the point F is to the left or right of the line AE.

Chapter X.—Replacement of Missing Field Stones.

As stated in the last chapter, survey stones, unless properly looked after by the ryots as required by law, often disappear or are buried or hidden by overgrowth. To find out exactly the proper position of the stone, the measurements already recorded in the course of field measurement as described in chapter VI should be laid out on the ground. Four methods are generally employed for finding out the position of a missing mark: (1) *The scale and bit method*, (2) *The calculation of chain and offset method*, (3) *The similar triangles method*, (4) *The intersection of perpendiculars method.*

The scale and bit-method in plane table and block map survey.

2. This method is most often adopted for stones planted under the Plane Table and the Block Map methods of survey in which separate diagonals are not given for each field but only long diagonals for whole blocks. The method is as follows:—

(1) Note the position of the missing stone in the field map.

(2) With the help of the field map, find two stones that are still on the ground and so situated that the line joining them passes close to the place where, according to the map, the missing stone should be.

(3) Place the wooden scale on the field map on the line joining these two stones and adjust the bit to form a right angle with the scale and the position on the map of the missing mark. Then, read off the length of the straight line between the two stones, the distance from either of the stones along this line, of the the point at which the offset to the missing stone should be measured, and the length of the offset. Then lay out these measurements on the ground with the chain and cross staff.

The position of the missing mark thus determined should be verified by measuring its distance from the adjoining field stones and comparing the result with the measurements noted in the map. It should be shifted slightly where necessary, so that large differences in one or more lines may be evenly distributed among all the lines meeting thereat.

3. Suppose stones 3 and 4 are missing in diagram No. 88. Look for stones 2 and 5 or 1 and 5. To measure between the two latter, if they exist, will probably be easier than between the two former as the field boundary will not have to be crossed, and it may prove to be an inconvenient obstacle. Read off with the scale and offset bit distances 1 A, A 3, 1 B, and B 4 on the field map. Suppose these distances to be 110 links, 45 links, 310 links, and 175 links, respectively. Measure 110 links along the line 1—5 on the ground, set up the cross staff at the point A, view 1 and 5 through one groove and direct a man through the other to stand at about the distance of the missing stone, and measure 45 links in that direction. The point arrived at will approximately be the position of stone No. 3. Similarly by measuring 310 links along the line 1–5 and then 175 at right angles to the left, the position of stone No. 4 will be found. To verify the points thus determined, measure the distances from stones Nos. 5 and 2 and from each other. Shift the positions slightly till the measurements tally with those noted in the field map within the limit of error allowed. If either point is a tri-junction as No. 4 in the sketch, another check, measurement may be made by consulting the maps of the adjoining survey fields Nos. 11 and 12. The position of a missing stone should always be verified by re-measuring at least three lines wherever possible.

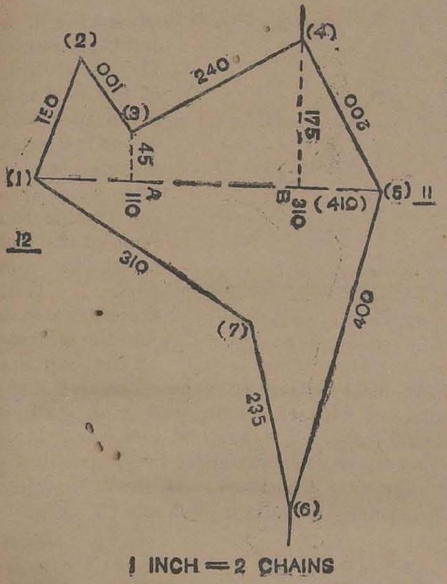


Fig. 88.

The scale and bit-method in simple triangulation and triangulation and offset surveys.

4. Under the triangulation and triangulation and offset systems of survey where diagonals are measured for each field, the method described above may be very conveniently adopted, since the chain and offset distances are already on record. We have simply to lay them out on the ground. It must be remembered that by reading off distances on the map with the scale, only approximate results can be obtained : diagonals which have previously been measured with the chain, therefore, should always be selected when they exist. The fewer the lines read with the scale, the better. The smaller the scale, the greater the chance of error. If, therefore, the field map is plotted to a scale of one inch equal to 5 chains,

so much of it as is necessary should be replotted to the scale of one inch equal to one chain, and on it the chain and offset distances should be read off with the scale and the bit.

5. Suppose in the triangle ABC, (Fig. 89), B is missing and A and C are *in situ*. If the plotting of the field map is not to a scale of one inch equal to one chain or two chains, plot the triangle to a scale of one inch equal to one chain. With the wooden scale and the bit, read off the chain distance from A or C and also the offset distance from D. The rest of the process should now be carried out with the chain and cross staff as already explained in paragraph 3 above. This method, however, seldom gives the exact position of the stone at once owing to the impossibility of reading off the distances sufficiently accurately. It must therefore be adjusted with reference to the measurements from A and C. Fig. 90 shows clearly how it can be done. 1 is the position as ascertained by the scale; 2 is 450 links from A; and 3 is 320 from C. These differences are reconciled by placing the stone at 4.

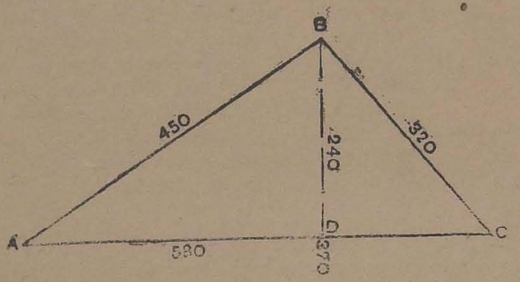


Fig. 89.

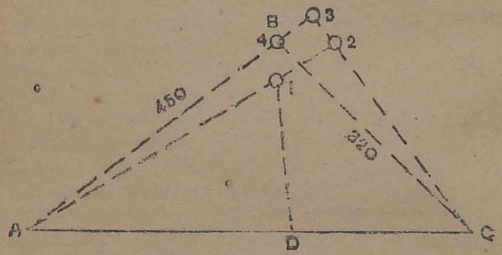


Fig. 90.

The calculation of the chain and offset method.

6. From the foregoing it will be seen that the exactness with which the position of missing marks can be ascertained depends to a very large extent on the correct reading with the scale and the bit, of the chain and offset distances of the missing mark on the field map. This method from its facility can be adopted where land is not very valuable and the approximate position of the stone is sufficient, but where valuable land is in dispute and the parties are litigious, the exact position of the missing mark requires to be ascertained to a link. This can be done under the triangulation and triangulation and offset systems of survey in which fields are divided into a number of triangles. If two stones in a triangle are existing, the chain and the offset distance to the missing stone in the same triangle can be found by the formula explained in

paragraph 10 of Chapter IX. In Figure No. 91 ABC is a triangle. B is missing and A and C are *in situ*.

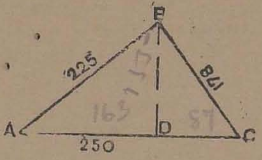


Fig. 91.

$$\text{Chain distance } AD = \frac{250^2 + 225^2 - 178^2}{2 \times 250} = 163.$$

$$\text{and offset } BD = \sqrt{225^2 - AD^2} = 155.$$

The chain distance and offset should be laid out on the ground and the point obtained should be verified by measurements taken from adjoining stones. Under this system, the adjustment will be very slight; whereas under the scale and bit system, a good deal of shifting of the original position is necessary.

The similar triangles method.

7. In simple triangulation and triangulation and offset methods of survey, the position of a missing mark can be found out also by another method called "*The similar triangles method.*" Two chains are ordinarily required for this method, but no cross staff is necessary (Fig. No. 92). In the triangle ABC, the stone at A is missing, B and C are *in situ*. Take

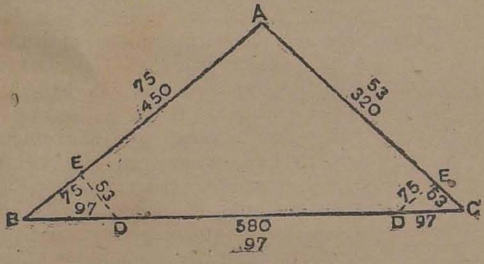


Fig. 92.

the longest of the three sides. Divide it by a number which gives as quotient the largest possible number of links in a chain not exceeding 100. BC, the longest side in the triangle should be divided by 6. The quotient is 97 links. As a rule it will be seen that if the length of the side is a few hundreds without odd links, the divisor will be made up of the digit in the hundredth place. If the length of the side is a few hundreds and odd links, the divisor will be greater than the digit in the hundredth place by one. As regards the length of BC, 5 is the digit in the hundredth place and it has also 80 odd links. It should therefore be divided by 5 + 1 = 6. If the length were 600 the divisor would be 6. Divide also the other sides BA and CA by the same number and write down the quotients 75 and 53 respectively. At 97 from B fix in the direction of C a peg D. Take two chains, hold the handle of one at the stone B, and of the other at the peg D. Now bring the 75th link of

the former and the 53rd of the latter together, so that they will meet at E, pulling the chains out tightly. A small triangle BED is thus formed which has its angles, equal to those of the large triangle BAC each to each and its sides have been made proportional. They are therefore said to be *similar*. Measure 450 from B in continuation of BE. The point at the 450th link is the position of the missing mark. Verify this with reference to the measurement of AC (320) and other lines meeting at that place and make the necessary adjustment.

8. The process is similar if C be the point chosen to start from. The difference lies only in the reversal of two sides of the small triangle and is clearly shown in the figure. This process is the same in principle as that involved in plotting with compasses with the difference that the former is done on the ground while the latter is performed on paper. As already explained, ill-conditioned triangles do not plot well, the process described above should not be followed in the case of such triangles.

9. Great care must be taken that the prolongation of the side BE is made in exactly the same line, otherwise AC will be considerably out. One chain alone can of course be used to carry out this problem, but in that case the two sides BE and ED would be together less than 100 links forming a very much smaller triangle. The larger BED can be made, the more accurately is A determined.

The intersection of perpendiculars method.

10. In many cases, the existence of bunds, ridges or other visible marks enables the surveyor to guess approximately the position of the missing stone without actual measurement, the approximate point not differing from the true one by more than 30 links. In such cases, the following process will be found quicker and easier. In Fig. 93, A and C are *in situ*. B is missing. The measurements of AB and CB are given. On an inspection of the bunds forming the boundaries of the field, D is found to be the approximate position of the missing mark. Measure 320 from A in the direction of D. At the 320th link (E) set up the cross-staff, view A through one groove and direct flags to F and G through the other.

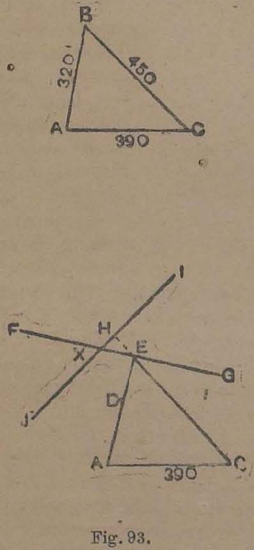


Fig. 93.

Next measure 450 from C in the direction of E and at the 450th link (H) set up the cross-staff, view C through one groove and direct flags to I and J through the other. X, the point of intersection of the two perpendiculars FG and IJ is the position of the missing mark. AX and CX should be measured and slight adjustments, if necessary, made as explained above.

Chapter XI.—Measurement of Sub-divisions in a Surveyed Field.

In Chapter VI the measurement of sub-divisions at the time of the original survey of a field has been dealt with. But subsequent sub-divisions may have to be measured and mapped in consequence of changes in the registration made under the Board's Standing Orders. The process of measuring sub-divisions is briefly described below.

Process of measurement.

2. Before commencing the field work, the surveyor should test the accuracy of the plotting of the field to be sub-divided. This discloses errors, if any, in the measurements taken during the original survey of the field and gives an opportunity to the surveyor to rectify them. The surveyor should then go round the field and identify all the boundary stones measuring a few lines here and there to check the correctness of their position. A few lines from adjoining fields should also be measured for verifying the position of trijunction points. He should replace and repair such of the stones as are missing or out of repair. He should next mark out the bends of the sub-division boundaries and the points of junction of the field and sub-division boundaries: and demarcate those points that should be demarcated in accordance with the orders in force in the district Then, the boundaries of the sub-divisions should first be measured. Next, the sub-division bends should be offsetted on the nearest diagonal of the field. The diagonals selected should, as far as possible, be those already measured in the original survey.

The measurements should be plotted into a tracing of the field map and after final verification as provided in Board's Standing Order No. 34A, the plotting should be made into the maintained atlases of field maps.

Measurement of detached sub-divisions in waste blocks.

3. Where in large waste blocks isolated plots are granted on patta, they should be measured, not as sub-divisions, but as independent survey

fields by the triangulation and offset method and connected with the stations in the main block by triangulation lines—*see* Fig. 94.

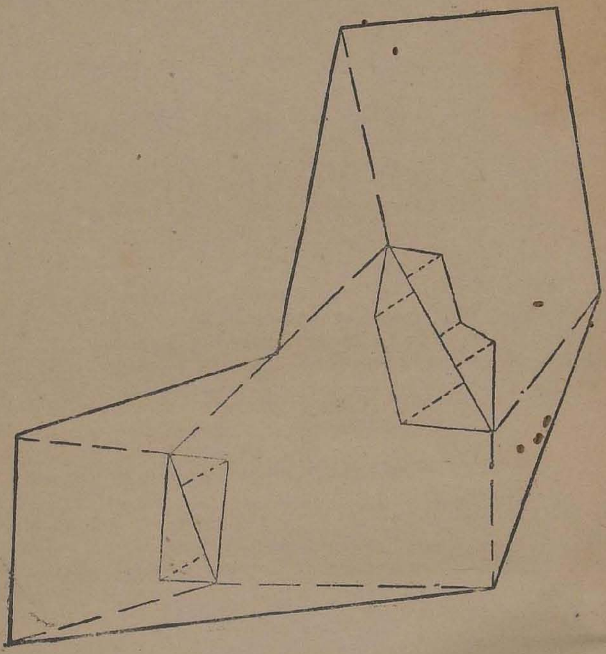


Fig. 94.

Notation of sub-divisions.

4. (*a*) The notation of new sub-divisions will depend on the notation of the survey fields and sub-divisions in the printed diglott register and should be such as to indicate the plot from which the new sub-division is made. If, in the diglott register, sub-divisions are denoted by numbers, new sub-divisions should be denoted by letters and *vice versâ*, *e.g.* (1) new sub divisions of settlement sub-division No. 14-1 should be denoted as 14-1-A, 14-1-B, etc.; (2) new sub-divisions of settlement sub-division No. 14-1-A should be denoted as 14-1-A-1, 14-1-A-2, etc. New sub-divisions of settlement S. No. 14 should generally be denoted 14-1, 14-2, etc., unless the district practice has been to use letter, *e.g.*, 14-A, 14-B, in which case this practice may continue; the main objects being to indicate clearly the origin of each sub-division, to preserve continuity of revenue record, and to facilitate search for, and identification of registered assurances.

(*b*) Further sub-divisions of post-settlement sub-divisions should be denoted by numbers or letters according as the post-settlement sub-divisions are denoted by letters or numbers, respectively.

APPENDIX I.

ARITHMETICAL TABLES.

Measures of length.

7·92 inches	=	1 link.
9 inches	=	1 span.
12 inches	=	1 foot.
18 inches	=	1 cubit.
3 feet	=	1 yard.
100 links	=	1 chain.
66 feet or 22 yards	=	1 chain.
220 yards or 10 chains	=	1 furlong.
8 furlongs or 80 chains	=	1 mile.

Square measure or measures of surface.

144 square inches	=	1 square foot.
9 square feet	=	1 square yard.
484 square yards	=	1 square chain.
10 square chains or 4,840 square yards	=	1 acre.
640 acres	=	1 square mile.
1,000 square links or 435·60 square feet	=	1 cent.
100 cents or 43,560 square feet	=	1 acre.

APPENDIX II.

INSTRUCTIONS TO OFFICERS IN CHARGE OF SURVEY SCHOOLS FOR KARNAMS AND REVENUE SUBORDINATES TOGETHER WITH A SYLLABUS OF PRACTICAL TRAINING FOR SIX WEEKS FOR A CLASS OF 20 PUPILS.

General instructions.

A survey school for the instruction of Karnams and Revenue Subordinates in Chain survey lasts for six weeks. The following general instructions will be observed by the officers in charge thereof:—

(i) As far as practicable, arrangements should be made to hold the Karnams' and Revenue Subordinates' classes at one centre. The latter should be instructed personally by the Land Records Tahsildar himself; and the former by the Land Records and Firka Revenue Inspectors and Land Records Deputy Surveyor under the general supervision of the Land Records Tahsildar. When the number of Karnams to be trained is too large to admit of all being gathered at one centre, arrangements should be made for the classes to begin at suitable intervals to enable the Land Records Tahsildar to be present during the first few days at each centre for the purpose of ensuring that the instructors understand their work. Where Karnams' classes are held at different centres, therefore, a class for Revenue Subordinates cannot be begun until after the Land Records Tahsildar has seen the Karnams' classes all satisfactorily started. But, where the class for Revenue subordinates is first begun, the Land Records Tahsildar may, when they are engaged on the independent field work part of the course, leave them for a few days in charge of his Deputy Surveyor or a Land Records Inspector in order that he may inspect Karnams' schools held elsewhere.

(ii) Karnams and candidates for the posts of Karnams seeking admission should be first tested in simple addition, subtraction, multiplication and division. Those found altogether ignorant of these processes should not be admitted into the school. Such men, if in service, should be reported to the Divisional officer for orders so that they may be removed from service.

(iii) The pupils should next be formed into as many classes as there are competent instructors available in the Land Records and ordinary Revenue Inspectors, but no class should contain more than 20 pupils. On the first day of the second week, each class should be divided into batches of four. As far as practicable, men of equal abilities should be put into a batch. The smartest of the four should be appointed the head of the batch.

(iv) In the case of karnams who had before been trained for six weeks but who have been found incompetent on examination in their villages and given another chance of training by the Divisional Officer, a fee of Rs. 5 should be charged. These karnams should be grouped in classes of not

more than eight. Each such class should be placed in charge of an instructor and should receive special attention from the Land Records Tahsildar.

(v) The instructor should see that each pupil provides himself with a copy of the Karnams' Survey Manual and has the following stationery ready :—

(*a*) A field book for drawing rough sketches and entering measurements.

(*b*) A book for plotting fields measured in the instruction and the independent course.

(*c*) A book for preparing demarcation block sketches for numbering stones.

(*d*) A book for writing the stones register.

(*e*) A book for preparing a statement of sub-divisions measured.

(*f*) A book for working exercises in the class and at home.

(*g*) A book for writing notes.

(vi) The instructor should provide himself with a black board and a few pieces of chalk. He should see that each batch is provided with a chain, cross-staff, offset pole, five flags and a dozen wooden pegs and that each pupil is provided with or provides himself with plotting scales, brass compasses, flat ruler, and area square paper.

(vii) As soon as a process has been explained, the batches should be told off to practice it under the immediate supervision of the instructor. At the close of the work for the morning or the afternoon, the portions in the Survey Manual relating to the matters taught should be read out and explained. Before dispersing the class in the evening, the instructor should invariably question the pupils for a few minutes on the subjects taught during the day and assign exercises for home work in them. Home work given in the evening should invariably be examined on the following day. If the instructor does not find time to check the work of all the 20 pupils constituting the class, the work of at least one in each batch selected at random should be inspected. The instructor should constantly inspect the registers detailed above and satisfy himself that each pupil is making fair progress. Pupils should attend the class at 6–30 in the morning and 2–30 in the afternoon. They should be dismissed at 11 A.M. and 5-30 P.M. An attendance register should be maintained with separate columns for noting the hour of attendance of pupils both in the morning and the afternoon.

(viii) The order of items, the work allotted for each day, and the methods laid down for instruction during the first three weeks of the course should be followed as far as possible, subject only to such deviations as the Land Records Tahsildar may deem necessary, to suit to special circumstances and requirements of the district.

2. *First week.*—The first week should be devoted to instructing the pupils in the definitions of simple geometrical terms, the construction and the use of the several survey and plotting instruments, the rules of demarcation, the measurement of fields and sub-divisions in unobstructed tracts, plotting and computation of area. The course for each day is prescribed hereunder :—

Day.	Morning.	Afternoon.
1	2	3
First day ...	The arrangement of the preliminaries detailed above.	Instruction in the extraction of square root and the explanation of the following geometrical terms :— A line, a point, a straight line, an angle, a right angle, an obtuse angle, an acute angle, a triangle, a right-angled triangle, similar triangles, a quadrilateral, a diagonal. a square, a rectangle, a trapezoid, a polygon, parallel lines.
Second day...	The construction of the Gunter's chain, arrows—Method of measurement—Duties of leader, follower and surveyor—Reading off links—Measurement where the closing or both the closing and starting stations become invisible after a certain length—Measurement on slopes, descent, ascent, running chain over prickly-pear and such like obstructions, walking in a straight line between two points, tracing a line in the direction of two distant points, testing chain (why a chain of 66 feet is used for revenue surveys—for Revenue subordinates only)—The tables of lineal, square and land measures.	The construction of the cross-staff, Method of using the cross-staff—first use: Measuring a right angle fram the chain line—second use: Setting off a right angle from the chain line to a spot where it is proposed to fix an object, offset—why long offsets should not be taken—why a right angle is formed on the ground—testing the cross-staff—construction and use of the offset pole.
Third day ...	Identification, in fields adjoining village boundary, of theodolite, field and sub-division stones, elementary rules of demarcation of fields and sub-divisions.	Properties of right-angled triangles and trapezoids— (1) Calculation of the third side in a right-angled triangle when two sides are known. (2) Where perpendiculars fall on a straight line from points on either side, how the distance between the points is calculated. (3) Relation between the sides of a right-angled triangle, where a perpendicular is drawn from the right angle to the hypotenuse. (4) Calculation of the fourth side of a trapezoid when three sides are known. [*Note.*—Item 3 is intended for Revenue subordinates only.]

Day.	Morning.	Afternoon.
1	2	3
Fourth day ...	(1) Preparation of a rough hand sketch and measurement of a field of 3 sides. (2) Next a field of 4 sides and division of it into two triangles by measuring a diagonal. (3) Next, a field of 5 or 6 sides and dividing it into 2 triangles—Principles of triangulation, First method : simple triangulation—second method : triangulation and offset method. Advantages of the second method—Process of measurement—recording of measurements.	(1) Instruments required for plotting :—scale—an offset scale, called the bit—compasses—scales of 80″, 40″ and 16″. (2) Additional plotting instruments—a drawing pen and a flat ruler for inking—method of plotting, plotting the morning work to different scales—The construction and use of the area square.
Fifth day ...	Preparation of a rough-hand sketch and measurement of a field of ten sides with two sub-divisions according to the triangulation and offset method—recording of details—correcting mistakes due to measurement with a wrong chain.	Plotting the morning work and computing the area with the area square; calculating mathematically the area of (1) a rectangle, (2) a triangle with an offset, (3) a quadrilateral with offsets, (4) a trapezoid, (5) a triangle by calculating chain and offset distances, (6) a triangle, without calculating the offset, (7) fields where offsets fall outside or inside the field boundary on a common diagonal. [Items 6 and 7 are for Revenue subordinates only.] Correction of areas of plottings prepared from measurements taken with an incorrect chain. (For Revenue subordinates only.)
Sixth day ...	Measurement of a narrow field running zig-zag for two furlongs and the explanation of the necessity for departing in such cases from the triangulation and offset method. The field selected should be measured first according to the triangulation and offset method and afterwards by offsetting all the stones on one convenient diagonal or on the longer of the two sides containing the right angle of a large right-angled triangle.	Plotting the morning work separately with the two sets of measurements and computing area with the area square and the explanation of the difference in shapes. Instruction in scales to be adopted for fields of different areas; procedure to be followed when scales of area square paper and plan differ—(for Revenue subordinates only).
Seventh day.	Review of the instruction given in the first six days.	......

3. *Second week mornings.*—In the mornings of the whole of this week, the pupils should be instructed in the measurement of obstructed lines. The nature of the obstruction and the method to be taught each day are noted below. A field to illustrate the description given should be formed with 10 sides containing three sub-divisions so that the line obstructed may be either a diagonal or a boundary of it. A rough sketch of the field should be prepared by each pupil and measurements taken according to the triangulation and offset method. The instructor should then explain the process prescribed for the day, by applying it to a line not obstructed and verifying the result with the length given by direct measurement. After the process is understood by the pupils, it should be applied to the line actually obstructed:—

Day.	General nature of the obstruction.	Illustration.	Process to be adopted.
First day...	I (*a*) Both stations accessible and visible from each other but not chainable.	A line obstructed by a tank or a bed of prickly-pear.	Construction of a rectangle.
	(*b*) Measuring an offset on a line obstructed as above.	Do.	Do.
Second day.	II (*a*) Both stations accessible but not visible from each other, nor the line between chainable.	A line obstructed by houses.	(1) Construction of a right-angled triangle or two equal right-angled triangles with cross-staff and chain. (2) Construction of a trapezoid on any line with cross-staff and chain. (3) Construction of two equal triangles with chain only. (4) Construction of two similar triangles with chain only.
Third day...	(*b*) Measuring an offset on a line obstructed as above.	Do.	(1) Constructing a rectangle by producing both ways the base of the small similar triangle formed in any triangle. (2) Converting a right-angled triangle into a rectangle (3) Forming a similar triangle in a right-angled triangle. (4) Converting a trapezoid into a rectangle.
Fourth day.	(*c*) Measurement where the offset itself is obstructed.	......	Construction of a rectangle.

Day.	General nature of the obstruction.	Illustration.	Process to be adopted.
Fifth day.	III (*a*) One of the two stations alone accessible and the other visible, but the line between them not chainable.	A line across an unfordable river. A stone with prickly-pear all round but visible.	(1) Construction of two equal right-angled triangles. (2) Construction of two similar right-angled triangles.
	(*b*) Measuring an offset on a line obstructed as above.	Do.	Same as processes 1 and 2 above.
	IV (*a*) Both stations visible but not accessible to the surveyor and therefore the line between not chainable from his position.	A line between two stations on one bank of an unfordable river, the surveyor standing on the other bank.	Construction of equal right-angled triangles.
	(*b*) Measuring an offset on a line obstructed as above.	Do.	Do.
Sixth day ..	V. Measurement of obstructed lines in special cases.	(*a*) Betel leaf gardens, village-sites and such other fields. (*b*) When a sub-division point in a field boundary is inaccessible and invisible. (*c*) Calculation of chain and offset distances on an obstructed line from those measured on another line.	
Seventh day.	Review of the instructions given in the previous days.		

[*Note.*—Processes II *a*—2, II *b*—2, 3 and 4, II—c, III, IV and V are intended only for Revenue subordinates. The karnam pupils should therefore repeat the first day's work in the fourth day, the second day's work in the fifth and the third day's work in the sixth.]

4. The afternoons should be devoted to—

(1) A repetition, on the blackboard, of the instructions given in the morning;

(2) The plotting of fields measured and computing area;

(3) Reduction and enlargement of plottings and conversion of scales (for Revenue subordinates only);

(4) Application of the formulæ for finding out sides of right-angled triangles and trapezoids, in checking the correctness of the measurements taken on the ground and in the system of 'purtalling.'

5. *Third week.*—The third week should be devoted to instructing the pupils in the maintenance of village survey records and the replacement of missing field stones.

The first thing to be done is to instruct the candidates in the—

(1) legal and executive rules for the maintenance of demarcation in Government land, issued in Board's Standing Order No. 34 A;

(2) preparation of demarcation sketches, stone registers and extracts of missing stones and statement of charges to be recovered for stones replanted or repaired.

For this purpose, a convenient block of about 100 fields should be assigned to a batch of four pupils, each of whom will prepare a demarcation sketch, number stones and write up the stone registers for 25 fields, noting down also the 'f' measurements. The instructor will take the pupils to the field and teach them how to inspect stones with the village map—demarcation sketch and record the result in the stone register. Each batch should then be told off to inspect its 100 field block and to render to the instructor extracts of stones missing or requiring repair. The latter should, in consultation with the Land Records Inspector concerned, arrange to get the necessary notification issued, so that the cases notified may be ripe for execution in the last week of the training course. The instructor should next select fields in which missing marks have been duly notified and are ripe for replanting, make arrangements for conveying stones to them and instruct the pupils in the following processes:—

I. Replacement of missing field stones—
- (i) The scale and bit method;
- (ii) The calculation of chain and offset method;
- (iii) The similar triangles method;
- (iv) The intersection of perpendiculars method.

Note.—Methods (ii), (iii) and (iv) are for Revenue subordinates only

II. Measurement of sub-divisions in surveyed fields, including cases of isolated plots in waste blocks.

III. Remeasurement of a case or two of fields surveyed but since found to be discrepant in shape or size.

6. In the afternoon, the sub-divisions, if any, measured in the morning should be plotted, sub-division statements prepared and the morning processes repeated on the blackboard.

7. *The fourth, fifth and sixth weeks—Independent field work.*—The pupils should be deputed for independent field work during the mornings of the last three weeks. A block of 120 acres comprising from 20 to 25 fields with a fair number of sub-divisions should be assigned to each batch of four pupils and two weeks assigned to the measurement and mapping thereof according to the triangulation and offset method. The Land Records Tahsildar may, in his discretion, raise or lower the acreage prescribed herein, having regard to the peculiar circumstances of the tracts surveyed. The blocks should, as far as practicable, be close to one another in the village in which the school is held. If work cannot conveniently be found for all the five batches of a class in one village (ordinarily it should) blocks in an adjoining village may be selected. A rough outline of the whole block with the interior fields and sub-divisions should be prepared by the instructor and given to the batch, and the pupils told to identify the stones before measurement is commenced. For those found missing or requiring repair, the pupils should apply to and obtain from the instructor the measurements necessary for determining their correct position, which, when found later on, should be marked by pegs. Where, however, a notification has already been issued and the period of 15 days has expired, arrangements should be made for planting stones at the positions thus found. The members of a batch should survey by turns, *i.e.*, when one surveys, the others should act as his chainmen and flag holders.

On the completion of the measurement of a field, the latter should copy in their own note-books the measurements recorded by the surveying pupil so that each may plot the field and compute area independently of the other. Thus every one of the pupils included in the batch should be made to plot and ink all the fields allotted for the batch and to find out their area. Neither Karnams nor Revenue subordinates should, on any account, be permitted to get the chaining done by coolies.

The third week of the independent course should be devoted to replanting stones in the hundred-field blocks inspected by them during the third week. Simple repairs which do not require measurement need not be attended to. For replanting, the pupils should obtain from the instructor diagonal measurements, wherever necessary and available. The instructor should, in consultation with the Land Records Inspector and the village officers concerned, make prompt arrangements to have stones conveyed to fields from the village depot. If sufficient work cannot be found for a batch in the block assigned, he should arrange to give them work in other blocks where the work is heavy. During these three weeks, the instructor should go round and inspect the work of two batches a day and note down his check-measurements in the records prepared. If any errors in survey are discovered by pupils in the course of the independent field work, they should be rectified and the records revised under the supervision of the instructor with reference to the rules in force in the district.

8. In the afternoons of the last three weeks—

(1) The pupils should assemble in the school and plot the morning's field work under the immediate supervision of the instructor.

(2) They should prepare statements for sub-divisions measured.

(3) They should also prepare statements of charges for stones replanted which should, after scrutiny and countersignature by the instructor, be forwarded to the Land Records Inspector concerned for necessary action.

(4) The instructor should scrutinize the records prepared from day to day and impart instructions when needed.

(5) The different methods of survey adopted and the records prepared in the Madras Presidency in the original, resurvey and revision surveys should be explained [Khasra system, the simple triangulation system, triangulation and offset system, the plane-table system and the block map system], the Karnam candidates being however instructed only as to the system adopted in the survey of their taluk or district.

(6) The method of correcting survey records, where errors are discovered, should be explained with particular reference to the rules in force in the district.

(7) Instructions given in the previous weeks should be thoroughly reviewed and the pupils asked to explain on the blackboard the various processes taught, particular attention being paid to the measurement of obstructed lines, the replacement of missing field stones and the maintenance rules.

9. The school should be closed on the evening of the last day and a report on the working thereof and also the records prepared by the pupils [registers (*a*), (*b*), (*c*), (*d*) and (*e*) referred to in paragraph 1 *supra*] should be submitted by the instructor to the Land Records Tahsildar. A special note should be made of the Karnams whose work requires to be carefully scrutinized in their villages. The Land Records Tahsildar will retain the records in his office and submit the report to the Divisional officer through the Taluk Tahsildar and the Land Records Superintendent. In the case of Revenue subordinates, the report together with the records should be submitted to the Collector through the Land Records Superintendent.